NEW ENGLAND WATER WORKS ASSOCIATION.

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This Association, as a Body, is not responsible for the statements or opinions of any of its members.

FALL EXCURSION.

SEPTEMBER 22, 23, 24, 1894.

The Fall Excursion of the Association, to the Crawford House, was a most enjoyable occasion.

The weather was perfect, the autumn foliage was beautiful, and nothing occurred to mar the enjoyment of those who participated.

A portion of the party made the ascent of Mount Washington, and were favored with a clear day and fine view. Others visited the historic Willey House and inspected the relics of the memorable land-slide.

The following is a list of those who attended:

ACTIVE MEMBERS.

George E. Batchelder, Registrar, Worcester, Mass.; Dexter Brackett, Asst. Engineer City Engineer's Office, Boston, Mass.; George F. Chace, Supt., Taunton, Mass.; R. C. P. Coggeshall, Supt., New Bedford, Mass.; Edwin Darling, Pawtucket, R. I.; Francis W. Dean, Mechanical Engineer, Boston, Mass.; Charles E. Drake, Civil Engineer, New Bedford, Mass.; Loring N. Farnum, Hydraulic Engineer, Boston, Mass.; B. R. Felton, City Engineer, Marlboro, Mass.; Desmond FitzGerald, Supt. Western Div. Boston W. W., Brookline, Mass.; James H. Higgins, Supt. Meter Dept., Providence, R. I.; David B. Kempton, member Water Board, New Bedford, Mass.; W. E. McClintock, Civil Engineer, Boston, Mass.; William McNally, Registrar, Marlboro, Mass.; Thomas Naylor, Supt., Maynard, Mass.; Edward H. Phipps, Supt. West Haven Water Co., New Haven, Conn.; George S. Rice, Civil Engineer, Boston, Mass.; William B. Sherman, Mechanical Engineer, Providence, R. I.; George A. Stacy, Supt., Marlboro, Mass.

ASSOCIATE MEMBERS.

Dean Steam Pump Co., of Holyoke, Mass., by F. H. Hayer; Charles H. Eglee, of Flushing, N. Y.; Gilchrist and Taylor, of Boston, Mass., by G. A. Taylor; Hersey Manufactnring Co., of South Boston, Mass., by J. E. Spofford and Samuel Harrison.

GUESTS.

W. E. Allen, Marlboro, Mass,; John H. Barrows, member Water Board, New Bedford, Mass.; Mrs. John H. Barrows, New Bedford, Mass.; Mrs. George E. Batchelder, Worcester, Mass.; Mrs. Dexter Brackett, Boston, Mass.; H. D. Brackett, Boston, Mass.; Mrs. George F. Chace, Taunton, Mass.; Mrs. R. C. P. Coggeshall, New Bedford, Mass.; L. D. Darling, Pawtucket, R. I.; Mrs. Francis W. Dean, Cambridge, Mass.; Mrs. James H. Higgins, Providence, R. I.; W. N. Hill, Marlboro, Mass.; Mrs. W. N. Hill, Marlboro, Mass.; Mrs. David B. Kempton, New Bedford, Mass.; Charles Marvin, City Messenger, Worcester, Mass.; Mrs. W. E. McClintock, Boston, Mass.; Mrs. William McNally, Marlboro, Mass.; Mrs. Thomas Naylor, Maynard, Mass.; Mrs. George S. Rice, Newton, Mass.; Mrs. M. T. Rogers, Marlboro, Mass.; E. I. Sawyer, Marlboro, Mass.; Mrs. E. I. Sawyer, Marlboro, Mass.; Mrs. William B. Sherman, Providence, R. I.; B. J. Smith, New York City; Mrs. J. E. Spofford, Boston, Mass.; Mrs. George A. Stacy, Marlboro, Mass.; J. E. Warren, Marlboro, Mass.; Mrs. J. E. Warren, Marlboro, Mass.

Total attendance 52.

EXPERIMENT WITH TUBE WELLS AT LOWELL, MASS.

BY

GEORGE BOWERS, City Engineer, Lowell, Mass.

[Read June 14, 1894.]

On the first of August, 1891, we began our experiments with tube wells by selecting a site on the north bank of the Merrimac river, above Pawtucket Falls, on which to drive our first wells. We chose this place because water, if found here, could be conveniently and economically pumped.

The first wells, seven in number, were three (3) inches in diameter with an open end, and were put down by the hydraulic jet process by D. L. Barker, of Providence, R. I. He used a temporary derrick about 30 feet high and a regular portable well driving machine.

The pipe used was in 19 foot lengths. After sinking the pipe as deep as possible it was pulled up about six (6) inches to allow the water to enter the lower end, then the well was pumped for several hours to clear it and the quality and quantity of the water tested.

In this work samples of the earth washed up by the water have been preserved, and the depth from which they came noted. This I found a very poor way of getting samples, as the earth would be badly mixed and the different strata not well defined.

The results obtained from the seven Barker wells were as follows:

No.	Depth.	Gals. per Min.	Color.	Taste.	
	ft. "				
1.....	21-0	40	Iron	Bad	
2.....	53-5	3	Smoky	Good	
3.....	67-5	10	Clear	Good	
4.....	72-8	30	Clear	Good	
5.....	90-3	15	Clear	Iron	
6.....	76-8	0			Worthless
7.....	69-5	9½	Clear	Good	

The results show conclusively that the stratification in this locality is too fine for the use of open end wells; so the Barker method was abandoned.

Mr. Barker and other driven well men of New England with whom I consulted explained to me the great superiority of open end wells over screened wells. Their arguments were, that while a screen well at first might give

just as much water as an open well, the screen would after a while corrode and the openings fill up with sand and rust, and the well become worthless.

I then consulted Mr. A. F. Noyes and examined with him the wells which he had driven for the city of Newton. These were all open end wells and connected with a filter gallery. The exact yield could not be obtained.

During the progress of the Barker work, Charles D. Pierce, of the Artesian and Oil Well Supply Company, of New York City, came to Lowell and explained the advantages of using screens of suitable construction, claiming that large quantities of water should be obtained in sand of the character shown by our Barker well samples.

A contract having been made with Mr. Pierce he began driving three-inch screen wells near the Barker wells. His method is as follows:

The screen with a steel shoe at the end of it is attached to a pipe which is then driven into the earth a short distance by means of a 150-pound drop-hammer; the earth is then removed from the inside of the pipe with a wash-pipe connected with a hand force pump. This operation is repeated every five (5) feet, this being the lengths of pipe used by Mr. Pierce.

In every case a Pierce well was located near a Barker well; the screens being driven to a depth corresponding with the best water-bearing stratum as shown by the Barker borings.

At the conclusion of Mr. Pierce's work his wells were subjected to a test capacity, each well being pumped one day by steam and the discharge accurately measured every 15 minutes. The measure of water from all the wells increased as the pumping continued, and gave far better results at the end of the day's pumping than at the beginning. As soon as the pump was stopped the elevation of the water was noted, and it was found to be the same as at the starting of the pump. The result of the Pierce work is as follows:

No.	Strain'r. Feet.	Depth of Well. Ft.	Water in Pipe Below S'face.	Well Pumped in Hours.	Gals per Min.	Color.	Taste
	′ ″	′ ″	′ ″				
1	5 1	68–4				Worthless	
2	10–0	29–0	2–0	6¼	59	Clear	Good
3	5–9	26–10	3–0	7½	51	Clear	Good
4	10–0	36–2	3–11	6¾	64	Clear	Good
5	10–0	20–0	9 0	4	50	Trace of Iron	Good

Chemical Examination.

Samples of water from the Barker and Pierce wells were analyzed by W. P. Atwood, chemist, of Lowell, and the State Board of Health. All the water was good except that from Barker well No. 1, located very near our filter gallery, which contained a large amount of iron and free ammonia.

BIOLOGICAL EXAMINATION.

STATE BOARD OF HEALTH,
CHIEF ENGINEER'S OFFICE, 13 BEACON STREET,
BOSTON, MASS., Dec. 8, 1891.

MR. GEORGE BOWERS, City Engineer, Lowell, Mass.

DEAR SIR:—I send herewith the numbers of bacteria per cubic centimeter found in the samples of water taken by Mr. Fales from the Lowell driven wells on December 2.

Name.	Bacteria per c. c. in Sample from Pump.
Pierce well No. 2	liquified
" " " 3	4
" " " 4	106
" " " 5 (20 feet deep)	29
Barker " " 4 (72 " ")	52

Yours truly,

F. P. STEARNS,
Chief Engineer.

The large number of bacteria in Pierce well No. 4 was a surprise to Professor Sedgwick, and other tests were made to see if the first test was correct. The next collection of samples was made January 8th, with the following results: 11:36 A. M., 30; 11:41. 1,210; 11:46, 348. The wells were pumped all the time with a hand pump.

On January 20th another test for bacteria was made from the same well beginning at 10 A. M. and continuing until 3 P. M., the well being pumped all the time and samples taken every 30 minutes with the following results:

Date and Hour of Collection.	Bacteria per Cubic Centimeter.	Date and Hour of Collection.	Bacteria per Cubic Centimeter.
1892.		1892.	
Jan. 20, 10.00 A. M.	280	Jan. 20, 1.00 P. M.	294
10.30 A. M	438	1.30 P. M.	426
11.00 A. M.	315	2.00 P. M.	210
11.30 A. M.	474	2.30 P. M	1,122
12.00 M.	417	3.00 P. M.	618
12.30 P. M.	480		

After Mr. Pierce had finished his work the Water Board authorized me to continue the experiments, employing our own water works men and using our own tools and purchasing all necessary supplies. I looked over Boston's well supply establishments and could not find a screen that I would use, and I very quickly saw why the well men objected to the use of screens; there were no screens in the market suitable for use on extensive works; they were good enough for a single house or farm supply, but were totally unfit for a

city supply. Not finding what I wanted, I was designing some, when Mr. William D. Andrews of New York called upon me. He showed me a sketch of his screen and brought official reports showing the large amount of water he had obtained for the city of Brooklyn. I saw at once that he had the screen that I wanted, and that he had the experience in driving wells that I wanted also. The latter was a difficult thing to obtain. Mr. Andrews would not give us the benefit of his very large experience without an agreement from the city that, after he had made his preliminary tests, he should have a contract for supplying the city with water and not be compelled to enter into competition with all the other well contractors in the country, who would bid, as he said, upon his judgment. Finally after a long struggle Mr. Andrews set his price, and a contract was made with him to continue our experimental work, using his own patent strainer and well driving tools, all to be paid for by the day, and all material rendered unfit for further use to be purchased by the city.

The first Andrews well was located at the river bank, south of Barker well No. 2, and was washed down to a depth of 87 feet to rock.

The ground at this place consisted of 21 alternate layers of sand and fine gravel. No water bearing material being found below 32 feet from the surface, the pipe was pulled up to that point and pumped, yielding 35 gallons per minute.

The water was of good quality, having a temperature of 46 degrees, which was 30 degrees cooler than the river at that time. Three hundred (300) feet west from here rock was struck at a depth of 13 feet below the surface, and 20 feet further west it was struck at 11 feet.

The finding of this ledge so near the surface was entirely unexpected, and may account for the small quantity of water obtained at the Barker well above mentioned.

From here we went up the river about 3,000 feet to a location where the land is low and submerged during high water in the river. Here we drove a gang of 10 wells with two additional ones to be used with Pierce well No. 3 for testing the ground water while pumping.

At first six wells were connected and pumped 39 hours and 50 minutes, yielding 482,884 gallons. Then two more were added to the gang and pumped 16 hours, total yield during this time 374,389 gallons. After this two more wells were added; these were pumped during the day time for about 6 days of 9 hours each, making a total time of 54 hours, 18 minutes, total yield 1,550,789 gallons. Then a continuous run of 9 days, 19 hours, 19 minutes was made, total amount of water pumped during this time 4,774,043 gallons, making an average yield per 24 hours of 486,905 gallons. Average depth of wells, 26 feet 8 inches. All wells are two-inch pipe with Andrews' patent strainers. The earth at this location consists of first, a layer of about 19 feet of very fine sand mixed with river silt, which is very compact and nearly impervious to water; next is a layer of about 6 feet of coarse sand; under this a layer of about 36 feet of quicksand. The circulation of the water in the ground was very free, and the water came back to its original level in the

wells very quickly after pumping was stopped. After pumping this plant by steam for about 10 hours, we detected a slight odor and taste of iron, which continued to increase until near the end of the pumping.

The analysis of the water from these wells was unsatisfactory, showing a large amount of free ammonia and iron in the water. The water, although not unhealthful, would be rusty in color and therefore would not satisfy consumers.

Our next test was made about 1,500 feet further up the river where the land is higher. A second plant similar to the one just described was driven, but at a greater distance from the river. The sand at the first place had a rusty color, but here it was clean and white; average depth of wells, 31 feet; average yield was as follows: Gang of six wells pumped 22 hours, 32 minutes, yield, 186,382 gallons.

Gang of eight wells pumped 16 hours, 33 minutes, yield, 167,537 gallons.

Gang of ten wells made a continuous run of 9 days, 21 hours and 10 minutes, yield 4,529,280 gallons. Average yield 10 wells for 24 hours was 458,337 gallons. The circulation of the water in the ground was free, and after a long run it came back to its original height in the wells in 50 minutes after the stopping of the pump. Four test wells were used to measure the ground water, the one on the north side was 150 feet, on the south 100 feet, on the west 86 feet, on the east 8 feet distant from the gang. A record was made every 30 minutes in the day time of each of the wells while running, with the following results:

Average fall in the well on the					North	side	2.1 feet.
"	"	"	"	"	South	"	2.2 "
"	"	"	"	"	East	"	5.9 "
"	"	"	"	"	West	"	2.0 "

The analysis of this water by the State Board of Health was satisfactory, showing it to be of very fine quality.

The tests have been very thorough and are very satisfactory, showing a good quantity of water obtainable from this location. Just how near the first plant water could be obtained without getting iron in it, could be found only by driving wells in that direction, and pumping them for a time by steam, as no iron appears when a well is pumped by hand.

Near the junction of the Merrimac river and Beaver brook was thought by several well men to be an excellent place for driven wells. That they were entirely mistaken was proved by the fact that out of nine wells driven here, only two yielded any water, and those only a small quantity.

These wells show that there is no water bearing stratum of sand or gravel here; the water which falls upon this ground runs off on the surface, which is quite wet.

All of these experiments had been made in the vicinity of the Merrimac river.

We now moved about a mile and three-fourths south of the Merrimac and a mile west of the Concord river to our present permanent location in the

valley of River Meadow brook. The land drained by this brook (an area of about 22 square miles) consists largely of sand and gravel making it an ideal place for wells.

Here Mr. Andrews drove sixteen wells, seven near together, which were afterwards connected and pumped, and nine wells distributed over an area of several acres.

The record of these wells is as follows: The first well was pumped every $2\frac{1}{2}$ feet in depth from 20 feet below the surface to 55 feet, and a careful record was kept of the amount of water obtained at each depth. At 20 feet the yield was 4 gallons per minute, at 28 feet 25 gallons, at 33 feet 7 gallons, and continued to increase to a depth of 45 feet; here the yield was 56 gallons per minute; from 45 to 55 feet the yield gradually diminished, until at the latter depth no water could be obtained.

From the depth of 55 feet this well was pulled up to a depth of 45 feet, when it yielded 55 gallons per minute; after being pumped one day by hand it yielded 70 gallons per minute.

The following table shows the depth of the wells, and also their yield when pumped by hand:

RIVER MEADOW WELLS.

No.	Depth.	Yield, Gallons per Minute.
1	39 feet	50
2	64 "	50
3	63 "	Could not drive lower, no water
4	30 "	Struck boulder.
5	39 "	70
6	48 "	55
7	40 "	Could not drive lower.
8	36 "	Used as a test well.
9	33 "	42
10	31 "	52
11	38 "	60
12	34 "	70
13	35 "	70
14	35 "	70
15	39 "	70

A gang of seven wells has been made here by connecting wells Nos. 5, 9, 10, 11, 12, 13 and 14 together, and they have been pumped by steam as follows:

Gang of six, run 9 hours, 24 minutes, total gallons pumped, 146,706. Average yield per minute, 260 gallons; average per well, 43 gallons.

Gang of seven, run 18, hours, 36 minutes, total gallons pumped, 291,997. Average yield per minute, 262 gallons; average per well, 37.4 gallons.

Continuous run of 73 hours, 44 minutes, total gallons pumped, 1,353,989. Average yield per day of 24 hours, 440,640 gallons. Average pumping per minute, 306 gallons. Average per well per minute, 43.7 gallons.

The analysis of the water from our experimental wells can be found in the report of the State Board of Health for 1892.

A record of the River Meadow Brook experiments was given the well contractors who were asked to bid on the specifications furnished for building a 5,000,000 gallon well plant here.

The following is an extract from the specifications giving a description of the work required, and the manner of making payments.

SPECIFICATIONS.

The contractor is to furnish all the material and do all the work necessary to construct complete, ready to attach a pump, a gang of tube wells of ample capacity to furnish, produce and supply 5,000,000 U. S. gallons of ground water each and every day of 24 hours, at a station to be hereafter definitely located by the city engineer upon land owned by the city of Lowell and used as a city farm, or upon land adjoining said farm near the River Meadow brook. The water to be of the quality obtained from the tube wells now constructed on the premises. Analysis of the water obtained from these wells by the State Board of Health is on file in the office of the Water Board.

The wells to be connected by suction mains and branches into one central receiver, which receiver shall have a faced, flanged opening of proper size with which the city will connect the suction pipe of the pump or pumps by air-tight flanged and bolted joints.

All the joints of the main suction and cross pipes to the central receiver to have faced flanges, gaskets and bolted joints.

Each well shall have a stop valve between the well and the suction main so as to shut it off from the gang.

The wells are all to be made with screens of a proper construction and grade to remove all sand from the water, and of a design approved by the City Engineer.

All pipes, connections, well heads and valves to be first class in every particular and all coated with a coal pitch varnish applied as directed by the City Engineer.

All well heads and stop valves to be provided with an iron gatebox so constructed that the well or gate may be readily used or inspected after the wells and connections are covered with earth to a depth sufficient to prevent injury by frost.

The quantity of water furnished and delivered by the wells will be measured by the pump or pumps furnished by the city.

The capacity of said pumps shall be determined by the City Engineer by wier measurement, and a careful record of the amount pumped shall be kept by the city, and a copy of the same furnished to the contractor. The city hereby agrees to set their pumps with center of water cylinders within five (5) feet of water level in wells.

The said contractor further agrees to furnish all the labor and material, engines, pumps, pipes and fixtures, including fuel necessary to make the

following temporary tests. After a group of about 10 wells has been constructed they shall be connected together temporarily and pumped by steam for a sufficient time to clear them of all sediment, and to ascertain the quantity and quality of the water, and if any well pumps sand or any other sediment it shall be pulled up and the defect remedied. If the water is unsatisfactory, the well or wells must be pulled up and a different location used. This process shall be continued until the entire water plant has been tested in the above manner.

The said city hereby agrees to make payment in the following manner:

After the wells have been constructed and the temporary test made, as above described, on the number of wells that is deemed by the engineer to be sufficient to yield 5,000,000 gallons per day (24 hours), 25 per cent. of the amount of the contract price will be paid.

After the wells are connected and pumped by the city for a term of 30 days, and if found to yield and deliver the full amount of 5,000,000 gallons per day, and the water is found to be good and of the same general quality as the samples taken from the test wells, an additional payment of 25 per cent. will be made. After the wells have been pumped by the city for three months, and if they still continue to furnish 5,000,000 gallons per day, an additional payment of 25 per cent. will be made; the final payment to be made after the wells have been pumped for one year and found to yield the full supply of 5,000,000 gallons daily.

Proposals were received from five bidders, price running from $8,500 per million to $4,850, the latter being the Cook Well Company of St. Louis, Mo.

A contract having been made with them, their representatives sunk 17 wells to test the material before beginning to sink permanent wells.

April 22d, Mr. Cook located the plant, and the work of sinking the permanent wells was immediately begun, and carried on as fast as circumstances would allow until September 16th, when the first test of quantity was made.

It was soon found that the formation of the earth was very irregular, and to follow any plan previously laid out would be impracticable; consequently, while trying to follow a general plan, the plan of wells when completed bore but slight resemblance to the original design. This place was full of surprises and difficulties; after getting a very good well at one point, the next trial might be a total failure, and the pipe would have to be pulled up and another location selected.

The wells vary in depth from 47 to 67 feet, the average depth being 52 feet. All are six (6) inches in diameter and made of the best quality of iron pipe.

Before the wells were connected and pumped by steam, the elevation of the water in every well was nine (9) inches above the level of the water in the brook; and as the level of water in the brook rose and fell, the elevation of the water in the wells changed just the same amount; the water from the wells always flowing into the brook.

The method of sinking wells used by the Cook people is very different from that employed in our former experiments. The pipe is sunk down by the

use of a sand bucket nearly as large as the interior of the pipe and about six (6) feet long. The bucket is raised and lowered by wooden rods connected together at the ends, so that when in the well they act as one rod and make the bucket very efficient in its work. This bucket removes all the material from the inside of the pipe, and when it is sunk in gravel stones five and one-half inches in diameter have been removed with it. While the earth is being removed, the pipe is gently turned or rocked and goes down by its own weight. This is a very rapid manner of getting pipe down through quicksand. In very hard gravel the pipe is sometimes driven a little with a heavy wooden weight. If stones too large to come up through the pipe are encountered, they are broken with a large drill, or, if this is impossible, the pipe is pulled up and the location changed.

Two push wells, so called, were put down in the spring. These wells are constructed by building a strong dam to press against and using a very strong clamp on the pipe. The pipe is pushed into the ground by the use of four jack screws. This is a very slow and expensive way, but allows a very long screen to be placed in a narrow stratum of water-bearing material, and has worked very well at other places, but here the material is not uniform enough to warrant the outlay. They are both good wells, but not enough better than the others to pay the difference in the cost.

All the wells are made with the Cook patent strainer, varying in length from eight (8) feet to seventeen (17) feet, according to the depth of the water-bearing stratum. The screens in the push wells are, one 24 feet and the other 42 feet in length.

After the screens are swedged into the well pipe and the well thoroughly pumped and washed by steam, the water is perfectly clear and no sand comes through the screen. The screens being made from a drawn brass tube, there is no chance for rust or corrosion, and to all appearances they are very durable, and they certainly are very fine specimens of mechanical skill.

A careful record of the depth of each layer of material is kept, and a great many samples showing the exact character of the earth in which the wells are situated have been taken and preserved. A record has also been kept of the amount of water each well yields when pumped by steam before being connected with the other wells.

The yield of 44 wells when pumped singly was over 5,000 gallons per minute, being at a rate of over 7,000,000 gallons per day. This quantity was thought to be large enough to warrant their being connected, and a test made of the quantity they would yield collectively.

The pumps were started and the water from 44 wells forced into the city mains on September 16th, the result being a supply of 2,000,000 gallons per day. At first the working of the pumps was greatly retarded by the leakage of air into them and also into the suction pipe and its branches. The trouble has been partially overcome by the stopping of every leak which could be detected.

In order to still further relieve the pumps an air pump was attached to the air chambers on the suction main; but this was not satisfactory, and some

other method for removing the air before its arrival at the pumps will have to be employed.

After a test of a few days it became evident to the contractor that he had located the wells too near together, and that they must be made to cover more territory. Experiments were at once begun to ascertain which of these wells could be cut off without affecting the quantity of water obtained. This resulted in the removal of 12 wells, leaving 32 from which 2,235,000 gallons have been pumped in 24 hours.

About the middle of October, after sinking a number of test wells, the plant was extended southerly to the Framingham railroad.

Eighteen wells were added and for some time pumped 3,000,000 gallons per day.

We then made some alterations in our pumping machinery, and added 22 4-inch wells, making a total of 72 wells, which constitutes our present plant. We are now pumping 3,300,000 gallons per day, with a vacuum of 23 to 23½ inches.

The water in our outside test wells now remains stationary, only rising and falling with the water in the brook, showing conclusively that our supply is greater than our draught.

THE WATER SERVICE AND FIRE PROTECTION OF THEATRES.

BY

WM. PAUL GERHARD, C. E., Consulting Engineer for Sanitary Works, New York.

[Abstract from a Paper prepared for the Annual Meeting June, 1894.]

Every effort is nowadays made to make theatre buildings as fire resisting and safe as possible.

I was recently engaged in the preparation of plans and specifications, and in superintending the installation of the water and gas service plant, and the fire extinguishing appliances of several modern theatres.

This paper, giving a detailed description of the general features and fundamental requirements of the water and fire protection service in theatres, is presented to the New England Water Works Association in the hope that it may prove of use to the members, and of general interest to all persons frequenting such places of amusement.

FIRE-EXTINGUISHING APPLIANCES.

A theatre building may be planned and constructed in a fire-resisting manner and with all due precautions to prevent the rapid spreading of the flames, yet in spite of all conceivable measures of safety a fire may break out, therefore ample fire appliances must be on hand and kept in constant readiness to fight the fire and to put out the flames. All fire extinguishing apparatus should be of the very best of its kind, and it should always be properly cared for and kept in working order for instant use.

A complete fire protection of a theatre must include:

(1) Outside fire hydrants.
(2) Inside standpipes, with fire valves, fire hose and fire nozzles, supplied from direct street pressure, or from
(3) Fire tanks, or from
(4) Fire pumps.
(5) An automatic sprinkler system, with elevated water tank and outside or fire department connection.
(6) A system of perforated pipes on the stage over the proscenium opening.
(7) Fire pails and casks of water.
(8) Chemical or portable fire extinguishers.
(9) A series of wet sponges on long poles.
(10) Wet woolen blankets, asbestos sheets and asbestos gloves, jumping nets, rope fire escapes and other life-saving appliances.
(11) Steam nozzles or jets, boxes of sand.
(12) Fire axes, fire hooks and knives.
(13) Fire alarm system.

Acknowledgment must, in this place, be made to the valuable services rendered to the cause of fire protection and fire extinction of all classes of risks, by the researches and labors of the engineers of the Associated Factories Mutual Fire Insurance Co. of Boston. I may safely assume that all the members of this association are familiar with Mr. J. C. H. Woodbury's papers on mill protection and on automatic sprinklers in particular, and with Mr. John R. Freeman's able specifications for fire pumps, for fire hose, and his elaborate and painstaking experiments on fire streams and fire nozzles. Taken together, these contain the most important facts upon the subject ever published, and the valuable conclusions reached by them may, with advantage, be applied to the equipment of fire service plants in theatres.

(1) Water Supply and Water Mains.

For the outside protection of theatres it is necessary that there should be a large water main in the street or streets where the building is located. The size of the main should be at least 8 inches in diameter, while a 10 or 12-inch main would be still better. To this main should be connected the various outside hydrants for fire department use, located in front of the theatre in sufficient number and at suitable distances apart.

The outside fire hydrants should preferably be frost-proof post hydrants, with four independent gate valve connections, so as to give an opportunity, where the pressure is ample, to bring into play a number of hose streams. The hydrants should be examined frequently during freezing weather, and their working parts must be oiled occasionally with heavy mineral oil.

A very abundant supply of water for a theatre building is necessary for fire protection.

The size of the water supply main run into the theatre is dependent upon the available pressure, and largely upon the number of fire valves in the building where these are supplied under direct pressure, or else upon the size and capacity of the fire pump installed. The New York Building Law, for instance, requires "the fire pump to be of sufficient capacity to supply all lines of hose when operated simultaneously," but in practice this requirement is never insisted upon, as it would lead, in even medium-sized theatres to pumps, water mains and steam boilers of unreasonable size. A "four stream" fire pump, delivering at the rate of 1,000 gallons per minute, and able to supply from four to five fire streams, rated at from 250 to 200 gallons per minute each, would require a 12-inch suction pipe. It would be next to impossible to secure from the city water department a connection of this large size with the main. As a rule, a 4-inch supply main is all that is conceded, although a 6-inch supply or two 4-inch supplies from different street mains and cross connected within the building, are undoubtedly much to be desired. It is, therefore, evident, that a reserve supply, stored in a large suction tank, should never be omitted, and the smaller the service pipe obtained, the larger should be the capacity of the suction reservoir.

The water available for fire protection must be ready under such a pressure as to permit the water to be forced in sufficient volume to all parts of the

building. As a rule, in our large cities, the direct or street pressure is insufficient for fire service. It therefore becomes necessary to supply the inside fire streams either from sufficiently elevated open fire tanks, or from closed tanks operated under compressed air. But such open tanks, even if placed above the highest part of the stage roof, would fail to give a suitable fire pressure—45 or 50 lbs.—except on the lower floors of the theatre. Closed tanks, operated by compressed air, require air compressors and engines, and this means further complications in the mechanical plant of the building. Therefore, fire pumps are usually substituted, and with an ample and sufficient steam boiler capacity, and steam kept at proper high pressure, give in practice the best results as regards fire pressure.

The 4 or 6-inch water main is usually made of heavy cast iron water pipe outside of the building, whereas in the building asphalted or galvanized wrought iron pipe with screw joints is used. It is necessary to place a shut-off valve on this branch outside of the building, so that in case of breakage of the inside water main the water would not useiessly run to waste and flood the cellar, and also so as not to reduce the supply to the outside hydrants. Particular care should also be taken to run the inside main where it would be at all times protected against injury.

(2) Water Meter and Bye-Pass.

Theatres, in this country, are private enterprises always erected, owned and managed by individuals, firms or corporations, and hence the water taken into the building is subject to the usual water tax. In most cases the water department insists on supplying the water by meter measurement. The water from the 4 or 6-inch main should therefore pass through a meter of corresponding size, and shut-off gate valves must be placed on each side of the water meter, in order to be able to disconnect and exchange the same in case of repair. It is, however, in my judgment, not only unnecessary but objectionable that in case of an emergency the fire pump should draw its supply through a meter. In several theatres, the fire protection of which was under my charge, I therefore endeavored to obtain from the city water department a full size bye-pass controlled by a gate valve. My intention was that this bye-pass valve should ordinarily be kept strapped and sealed with a seal of the water department to prevent the unlawful use of the valve, and that it should be cut and the valve opened only in case of fire, so as to admit a direct supply to the fire pump. I learn that such bye-passes are granted for this purpose in France and Germany, but I was unable to convince the New York City Water Department of the desirability of such a device and the bye-pass arrangement proposed did not receive the approval of the authorities, although no good reason was given for the refusal.

(3) Shut-Offs and Gate Valves.

All supply mains and the distributing service pipes in a theatre should be controlled by valves made of gun metal, in the best manner, and only the best quality of valves should be purchased. Globe valves should not be used,

gate valves being much preferable because they have a full water way. At the pumps, angle valves may be used on the suction pipes. The fire lines starting at the fire pump and connecting with the stand pipes should preferably not have any shut-off valves, or else if valves are used, they must be kept open and strapped, otherwise it may happen in a case of emergency that on turning open a fire valve no water will be had, the gate valve on the line having been accidentally closed in the cellar. All valves should be provided with wheel handles, and these should be marked with arrows indicating the direction in which they open. It is also recommended to provide all water valves with tell-tales showing automatically at all times and at a glance whether the valves are open or closed.

(4) Fire Pump.

The fire pumps installed in theatres are either rotary steam pumps, of the fire engine type, or else direct acting steam fire pumps. Excellent rotary steam fire pumps are made by manufacturers of steam fire engines, but in theatres the direct acting pump is used to a much greater extent. While the ordinary so-called fire pumps will answer the purpose, it is advisable to use in theatres the best procurable kind of pump. Of these the "Underwriter pattern" steam fire pump is, without doubt, the most advanced and most serviceable type of direct acting pump. This pump differs from the ordinary direct acting fire pump in several points, of which the following are the most important:

(1) The steam ports and the water passages are made more direct and from 25 to 50 per cent. larger, the suction pipe and the air chambers are increased in size correspondingly, so as to make the pump more powerful and able to deliver a larger volume of water, without water hammer, and so as to permit the pump to run at high speed.

(2) The principal working parts of the pump are made rust proof, so as to permit the pump to start instantly after long periods of disuse.

Underwriter fire pumps are now manufactured by all the principal manufacturers of direct acting pumps, and nearly all of them have adopted a 12-inch stroke as preferable, although a few still adhere to a 10-inch stroke.

[Space does not permit to give here a resume of the principal sizes and of the details of Underwriter fire pumps.]

As regards the size of fire pump required for a theatre, the minimum size, to be used for small theatres, would be a two-stream pump, having a capacity of 500 gallons per minute. For medium-sized theatres, I would recommend the use of the four-stream pump, supplying 1,000 gallons per minute, and for large theatres, either the six-stream pump (capacity 1,500 gallons), or better, two four-stream pumps (combined capacity 2,000 gallons).

Although a large theatre may be provided with from 25 to 50 fire valves, the requirement that the pump should supply all the streams simultaneously, as it reads for instance in the New York Building Law, seems to me altogether unnecessary, and in practice it is never insisted on. As is well known, most of the theatre fires have their origin on or about the stage, and all that can be reasonably required is that the half a dozen or so fire valves operated at

these points should supply a full and effective stream. If the fire has already gained so much headway that it cannot be checked or controlled by the hose streams on the stage, persons would rarely be found who would risk their lives by staying in the burning building to handle additional streams. At such time, the building had better be turned over to the city fire brigade and their fire engines. The chief object of the inside fire valves is to fight local fires before they have gained any considerable headway. [Details concerning the fitting up of fire pumps in theatres are here omitted for want of space.]

(5) Suction Reservoir.

Ordinarily, the fire pump, as well as the boiler and house tank pumps, should draw their supply from an open suction reservoir, and not directly from the supply mains. This suction tank, if suitably large, would act, in case of a fire, as a storage reservoir for the fire pump. It is, therefore, advisable to make this tank as large as the space at disposal and the available means permit. A 2,000 gallon tank should be considered the minimum size, but, where it can be obtained, I should advise using at least a 10,000 gallon tank. This would give to a four-stream fire pump a reserve supply lasting at least 10 minutes, with the pump going at full speed.

The suction reservoir is usually made of boiler iron sheets, well and tightly riveted together, and strongly stayed and braced. It is supplied from the theatre water main by a number of ball cocks of large size. To guard against overflow in case the ball cocks get out of order, it is provided with a large overflow pipe carried over a trapped and sewer connected sink. The suction tank is connected with the fire pump by a suction pipe of diameter corresponding to the size of the pump, and it is also connected with the other steam pumps constituting together the pumping plant.

The suction end of the fire pump is also connected with the direct supply from the street main. It is advisable to cross-connect all pumps in this manner, so that in case the reservoir is emptied for cleaning or other purposes, the pumps are enabled to draw water directly from the street. The suction pipe of the fire pump varies from 8 to 12 inches according to size, and where it connects with the street main, which, as stated above, is rarely larger than 4-inch, a suitable reducing fitting should be used, and the use of bushings should not be permitted.

A still better fire protection would be obtained by providing two independent supplies to the fire pump, from mains on different streets, so that in case the fire engines have arrived and being connected to the fire hydrants in front of the theatre exhaust the capacity of the main in front of the theatre, the inside fire pump would still be kept supplied with water by the second independent main.

(6) Fire Stand Pipes.

At suitable points in the four sub-divisions of a theatre, fire stand pipes, with fire valves and hose attached, should be placed. The largest number of fire valves is required on or about the various levels of the stage where a fire is most likely to break out. There should also be fire stand pipes in the auditorium, in the corridors and lobbies, and near the dressing rooms, with

outlets for fire valves on each floor or tier, and the valves should be so distributed that the remotest corner can be reached by the fire hose.

The number of stand pipes required and their position depends therefore upon the size and area of the theatre and upon the length of the fire hose attached to the fire valves. The New York City Building Law requires that one stand pipe be provided on each side of the stage, with outlets on every floor and gallery from the under stage to the rigging loft, one stand pipe on each side of the auditorium, with outlets in each tier from the cellar to the gallery, one in the property room, and one in the carpenter's shop. Thus, in the new Harrigan Theatre, there are four lines, and in the new Fifth Avenue Theatre, five lines of stand pipes. Larger theatres would require a still greater number.

The stand pipes vary in size from 2 to 3 inches, but it is advisable to make 2½ inches the minimum size. All stand pipes should stand entirely free from the walls. Each line should be connected directly with the fire pump in the engine or boiler room, and there should be no shut-off valve at the pump. The usual material for stand pipes is galvanized wrought iron. In view of the fact that the pipes have to stand an internal fire pressure of about 100 lbs. per square inch, and sometimes strong shocks and jars from water hammer, it is advisable to use double or extra heavy wrought iron pipes. Tinned and annealed brass pipes would, undoubtedly, be preferable for fire stand pipes on account of their greater interior smoothness, but the cost of brass pipe generally precludes their use.

The vertical stand pipes should be run as straight as possible, avoiding offsets which mean increased friction. Likewise, should the horizontal lines connecting the stand pipes with the fire pump be run as direct and with as few changes in direction as possible. Where changes are necessary, it is far better to use 45° elbows, and right-angle elbows should be entirely avoided.

The New York Building Law stipulates that the fire stand pipes must be connected only with the fire pump, and not with the fire tank, supplying the sprinkler system.

In many theatres of Europe, provision is made for large storage tanks placed over the highest part of the stage, and filled partly with water and partly with compressed air, of at least 75 lbs. per square inch pressure, and in this case the fire valves and stand pipes are supplied from these special fire tanks, which may also supply a system of perforated pipes placed over the stage. This would in case of an emergency, serve to deluge the stage and stage scenery with water.

(7) Fire Valves.

At each outlet of the fire lines, and also at the fire pump, there should be provided a fire valve. Straightway gate valves of best gun metal are the best, and they are preferable to angle globe valves, although the latter have the advantage of permitting the hose to hang down straight, and thereby avoid the possible "kinking" of the hose at the valve outlet.

Fire valves should be of the best obtainable make, as those of poor quality and bad workmanship are liable to become stuck in the seats.

The size of the fire valve varies from 1¼ to 2½ inches and in cities, where this matter is regulated by building laws, the standard fire department size, viz: 2½ inches is called for.

(8) Fire Hose.

Only the best kind of hose is suitable for use in a theatre, and no expense should be spared in this direction. It is true that often the cheapest kind of fire hose with rough inside and only made "to sell" is provided, merely to comply with the requirements of the law or of the underwriters. But a poor quality of hose, hung up for inspection or exhibition purposes only, will invariably prove worthless, and leak like a sieve, or burst, when needed in an emergency.

The fire hose may be leather hose, or solid rubber hose, or linen or cotton hose lined with rubber, or finally unlined linen hose.

Leather hose is very expensive, besides being stiff and unwieldy, and for these reasons it is not much used, and the same may be said of solid rubber hose. The choice for theatres lies between unlined linen and rubber lined cotton hose.

Good woven linen hose can be obtained which is practically water tight, except for a slight sweating, under pressure, at the beginning, and which is able to stand a bursting pressure of from 300 to 400 lbs. I should favor for indoor use in theatres the use of unlined linen hose, which is not so heavy and difficult to handle as rubber lined hose. Carefully woven hose may be obtained in brands which have as much smoothness of the inside as is ordinarily required. While rubber lined hose may be tighter, and therefore will prevent unnecessary damage by leakage of water when new, it is my judgment, that when hung up in a theatre and perhaps not used for a long period, the rubber lining will crack or disintegrate, and then the hose will be less useful than a good brand of carefully woven unlined linen hose, which, if kept dry, will last for many years.

Moreover, while I am fully cognizant of the great loss of friction occurring in fire hose smaller than 2½ inches in diameter (the loss by friction in a 2½ inch hose is stated by Mr. Freeman to be only ⅓ of what it is in a 2-inch hose), I am inclined to favor for inside use in theatres, as well as in other public buildings and institutions, the use of 2-inch, or better even 1½-inch hose, together with a smaller size of fire nozzle. Such an outfit would be lighter, more compact and more convenient for quick use. All inside fire hose in theatres is primarily and chiefly intended for use in an emergency by the theatre employes, who are seldom, if ever, trained firemen. It is intended for putting out quickly a small fire during its first stages. When a fire in a theatre has once reached a stage where it calls for the action of the city fire department, the heat and smoke of the fiercely burning fire would be so great as to drive the men back and render the inside fire valves nearly or quite useless. The standard 2½-inch rubber lined, or even the unlined hose, are much too heavy to be handled with success by ordinary employes. Few men, indeed, realize that it requires the full strength of two firemen to hold a

standard fire nozzle under a water pressure of only 50 pounds, and that an inexperienced man cannot hold a fire nozzle if the pressure exceeds 25 or 30 pounds.

(9) Fire Nozzles and Couplings.

The fire hose should be provided with well fastened couplings. If the hose is 2½ inches in diameter, the couplings should be of standard fire department size, shape and thread, and the coupling must not be obstructed by washers projecting on the inside.

Each length of hose must be provided with a well finished strong brass nozzle. There are numerous shapes and patterns of nozzles or "play pipes." Whatever pattern may be chosen, the inside of the nozzle must be absolutely smooth and as true as a gun barrel. Smooth plain nozzles are the best and there is no advantage in using ring nozzles. Mr. Freeman's experiments on fire jets and fire nozzles established the fact that the discharge stream from a ring nozzle is 25 per cent. less than that from a smooth plain nozzle.

Short nozzles, about 1 or 1½ feet long, are not so easily handled as long nozzles, and their shape is not such as to throw the most efficient jet. It is always better to provide swivel handles at the base of the play pipe, these being useful not only in holding the nozzle, but also in carrying the hose up a ladder, or in shifting hose. The best form of nozzle for 2½-inch hose is probably that designed by Mr. Freeman, and which may be obtained from all dealers in firemen's supplies under the name of the "Underwriter" or "Factory Mutual" pattern of play pipe.

The principal dimensions of such play pipes are: Length over all 30 inches, diameter at base of play pipe 2½", diameter at base of standard nozzle 1¾", diameter of opening of nozzle 1⅛".

It is best to make the play pipes and nozzles of polished brass or gun metal, and it is a good plan to have the body of the play pipe wound outside with cord to permit a better grip, and to prevent coldness to the touch. Rubber and cotton fabric play pipes are not as durable, for both the rubber and the cotton are liable to rot.

Where 1½" hose is used for inside protection the fire nozzle opening need not be larger than ⅞". Beware of cheap nozzles, made of light or thin brass, rough on the inside, and which easily become dented, battered or bruised.

(10) Monitor Nozzles.

A very excellent device for fire protection, and one which seems particularly adapted for the fire protection of the stage, the fly galleries, and the rigging loft, is the so-called "Monitor Nozzle."

It consists substantially of a play pipe attached to a revolving chamber, and provided with means for lowering or raising the play pipe, thus permitting the hose pipe to be inclined or elevated at any angle desired, and to be turned into any direction horizontally. Such a device enables the attendant to cover any desired point with the fire stream. This nozzle is similar in construction and operation to the large and very powerful nozzles now used on "fire boats."

(11) AUTOMATIC SPRINKLER SYSTEM.

We have, in the foregoing, considered one essential form of fire apparatus for the protection of theatres, namely, the fire pump, with its direct street supply and suction connection from a reserve reservoir, with its connections to numerous fire stand pipes, scattered over the theatre, and each provided with a number of fire valves with fire couplings, fire hose, play pipes, hose racks and spanners, or with Monitor fire nozzles. The theatre employes should be entirely familiar with this apparatus and must be thoroughly drilled in its use.

We must next consider a second essential system of fire protection of the stage, consisting in the equipment of an automatic sprinkler system.

The automatic sprinklers which are now so universally fitted up in mill buildings, factories of all kinds, and in warehouses, have also been introduced some years ago in the theatres of the United States. There are instances on record where the timely opening of such sprinklers, at the outbreak of a theatre fire, has saved the building from destruction, The fires at the Union Square Theatre in New York City, on Feb. 28, 1888, and at the Providence, R. I. Theatre Comique, in November, 1882, are such instances.

I do not know of a single instance where a European theatre has been fitted up with sprinklers, the perforated pipe system and water curtain, of which I shall speak further on, taking there the place of the automatic sprinklers.

As is well known, there are three principal sprinkler pipe systems, namely, (1) the ordinary wet pipe system; (2) the non-freezing wet pipe system; and (3) the dry pipe system.

The ordinary wet pipe system is the one in most general use. It is open only to two objections, first, that in buildings not constantly or sufficiently heated it is liable to freeze, and thus become inoperative just at a moment when wanted, or to do damage by water by the bursting of the frozen pipes; second, that in the event of a sprinkler head becoming defective or damaged and opening, it is liable to cause damage to the building or its contents by flooding same with water. It may be stated that the best sprinkler heads in the market are now so perfected as to almost preclude such accidental bursting of a head.

The second, or non-freezing wet pipe system, has an open water tank, and a small air-tight iron tank feeding the pipes, which are filled with a non-freezing and non-corrosive liquid. It is used where the building, in which the sprinkler system is installed, cannot be heated. The two tanks are connected by a syphon, so that when a sprinkler opens, the system is fed from the water tank. This system is open to the objection of possible leakage, and, moreover, a possible corrosion of the sprinkler heads.

The third, or dry pipe system is extensively advocated for buildings in which water pipes would be liable to freezing.. There are several modifications of this system, the pipes in one system being filled with compressed

air instead of water. In all of these there is great difficulty in making the system absolutely air-tight. Air pumps are generally provided to keep the air pressure up, and the system must be frequently watched. An improved dry pipe system has in addition to the sprinkler pipes and heads an independent air pipe with fusible solder plugs, and when one of these is operated by the heat of a fire an automatic valve is opened admitting the water from the tank to the pipes.

In theatres, the temperature can be at all times kept up to a sufficient degree of heat to insure the non-freezing of the water in the pipe system, and therefore it is the rule to instal the ordinary wet pipe system.

It is the purpose of an automatic sprinkler system to extinguish a fire in its incipiency, through the agency of the fire itself. A fire if started, opens up only a limited number of sprinkler heads, hence there is no useless waste of water, no unnecessary damage, and the water discharged is concentrated in the spot just where wanted.

A wet pipe sprinkler system comprises a wooden Cooper's tank, placed on the highest part of the stage roof, and of a capacity corresponding to the number of sprinkler heads. The installation for a theatre requires generally from 100 to 300 sprinkler heads, suitably distributed, several 1½", 2" and 3" risers, a separate shut-off valve, for each floor or tier, a 2½" to 3" riser from the pump to the tank, a watchman's automatic fire alarm with large gongs, one on the stage, the other on the outside of the building, a low water alarm with indicator in the pump or engine room, one or more 3-inch pipes running from the main riser to the outside of the building, to form a fire department connection (for auxiliary supply) which is provided with check valve.

It is essential that all sprinkler systems should have two independent approved sources of supply, of which one should be always turned on. Speaking generally, the supply to the sprinkler system may be either from a roof tank, or from reservoir pressure, or from direct pressure from public street mains, or from special sprinkler fire pumps, or from fire department steam engines by means of the outside fire department connections.

Sprinkler heads must be made of non-corrodible metal, and the fusible solder must be of such a composition that it will be released at 155°-160° Fahrenheit. The solder joint of all sprinkler heads must be so located that when it is acted upon by the fire and about to be released, no water or its immediate chilling effect can reach the solder and prevent it from opening.

It is essential that the fusible solder joint should be absolutely reliable, sensitive, and that it acts quickly and promptly. All sprinklers must open full way, and each sprinkler out-let must deliver about 1 cubic foot of water per minute under the available pressure. Sprinkler heads must be able to sustain a pressure of 300 lbs. per square inch, without leaking, and they must be capable of operating under 5 lbs. water pressure.

All sprinkler heads are provided with distributors or deflectors, which divide the stream of water, as it strikes them, into a heavy shower, which

thoroughly drenches the fire. These deflectors are stationary in some sprinklers, in others they are revolving or oscillating. The sprinkler heads are placed either above or below the distributing pipes, the former position being slightly preferable because it secures perfect drainage and prevents the lodgment of rust, dirt, or sediment in the sprinklers.

The ordinary fusible solder joint, which opens at 155°-160° Fahr. is not adapted for boiler rooms or drying rooms, owing to the sometimes excessive heat in these rooms. If automatic sprinkler protection is desired in such places, a different alloy or solder, having a higher degree of fusibility should be used.

The number of sprinklers necessary for an equipment depends upon the areas to be protected.

Sprinkler heads must be set at no greater distance than 10 ft. apart, and 5 ft. away from walls or partitions so that they protect an area of 10 ft. in diameter. The rules of the New York Board of Fire Underwriters call for all portions of a building to be equipped by sprinklers, unless especially exempted because of being entirely fireproof and containing only non-combustible materials, as, for instance, the loft over the auditorium, but in the stage portion of a theatre, it is important that the space between ceiling or rigging loft and stage roof be also protected. The largest number of sprinklers in a theatre is required to protect the rigging loft, and under it to protect the stage.

As a rule, the piping of the sprinkler system consists of plain standard wrought-iron pipes. If the pipes are constantly kept full of water there is probably not much danger of their rusting. In the dry pipe system, however, it is essential that the supply pipes should be rust-proofed or galvanized, and where economy is no object, it is also better to use such piping in the wet pipe system.

As regards sizes for the sprinkler risers, distributing pipes and branch pipes to the individual sprinklers, the following rules should be strictly adhered to:

(a) The mains from the tank (or from the outside connection) must be of a capacity to supply at least 50 per cent. of all sprinklers fed in the largest space enclosed by fire walls; but where such a space would require less than 20 sprinklers, the main should be capable of supplying 75 per cent. of them.

(b) All branch pipes supplying more than five and less than ten sprinklers, shall be calculated to be of a capacity to supply 75 per cent. of the sprinklers.

(c) Where over 30 sprinklers are supplied by one branch, it must have a capacity of supplying 50 per cent.

(d) No pipe smaller than $\frac{3}{4}$" shall be used, and only one sprinkler is to be fed from a $\frac{3}{4}$" pipe, provided the feed pipe is not longer than 30 feet.

(e) The piping may be calculated from the following table, which gives the greatest number of sprinkler heads to be fed from pipes of different di:

ameter, those in column I being given by Mr. J. C. H. Woodbury, those in column II being the requirement of the N. Y. Board of Fire Underwriters, those in column III being the Philadelphia Board of Underwriters' requirements for mercantile buildings, and textile mills, and in column IV for special risks, including theatres:

Size of pipe in inches.	Number of Sprinkler Heads allowed.			
	I.	II.	III.	IV.
3/4"	1	1	1	1
1"	3	3	3	3
1 1/4"	6	5	6	5
1 1/2"	10	9	10	8
2"	18	16	18	15
2 1/2"	28	25	28	24
3"	46–48	36	46	35
3 1/2"	70–78	48	70	48
4"	95–115	64	100	63
4 1/2"		82		
5"		100	250	100
6"		144	over 250	150

All mains, branches, and connections must be so arranged with drip pipes and drip valves that they can be completely emptied.

Each main and riser, and each distributing pipe on each floor, is to be provided with gate valve, placed in the case of the mains near the tank. All valves to be full water way gate valves, with telltale indicators, and all valves must be strapped open by leather riveted or sealed straps.

All exposed sprinkler heads must have guards placed around them to protect them from damage.

The roof tank supplying the sprinkler system should be placed on the highest part of the stage roof, and must be elevated so that its bottom will be at least 12 feet above the level of the highest sprinkler. This location of the fire tank on the roof is open to the objection that in case of fire the tank will fall with the collapse of the roof or the bearing walls, and may thus become a source of danger to the firemen. Where it can be done, it is preferable to build a separate tank tower.

The roof tank must be of large capacity so as to be able to supply the sprinklers opened during a fire for a certain length of time.

Some require the capacity to be such as to fully operate for one hour at least 75 per cent. of all sprinklers located in the largest room enclosed by fire

walls. For instance, if there are 50 sprinklers over the stage of a theatre, the capacity of the tank would figure as follows:

$$50 \times \tfrac{3}{4} \times 1 \text{ cub. ft.} = 37.5 \text{ cub. ft. per minute or}$$
$$= 37.5 \times 60 = 2250 \text{ cub. ft. per hour}$$
$$= 16{,}875 \text{ gallons tank capacity.}$$

The New York Fire Underwriters' rules require the tank to be of a capacity to feed for 15 minutes 50 per cent. of all sprinklers supplied, located in the largest compartment enclosed by fire walls. This, for 50 sprinklers over stage, as above, would require

$$50 \times \tfrac{1}{2} \times 1 = 25 \text{ cub. feet per minute}$$
$$= 375 \text{ cub. feet per one quarter hour or}$$
a tank capacity of about 2,812 gallons.

At the Fifth Avenue Theatre in New York, a roof tank of 6,000 gallons capacity was installed for a total equipment of 227 sprinklers, distributed as follows: Under the stage roof 44, under the gridiron or rigging loft 50, under the first and second fly galleries 12 and 9 respectively, under the stage 40, and for the dressing rooms 72.

In the new Harrigan Theatre in New York, the capacity of the roof tank was 4,000 gallons, and the total number of sprinklers installed was 105.*

(12) Perforated Pipe Systems.

In some instances, the stage of theatres is fitted up with an open sprinkler system, or else with a perforated pipe system, in place of the automatic sprinklers. In both cases the pipe system is empty except when in action, the water, whether supplied from direct city pressure or from one or several elevated reservoirs, being held back by a valve, which is either operated by hand, or else fastened by a hemp cord which is supposed to burn at the outbreak of a fire, thereby releasing the valve. The perforated pipe system is arranged near and above the rigging loft and consists of a number of sections or rows of pipes each controlled by a separate valve or shut-off and fed from a large cross main. These valves are all operated from one point on the stage and the attendant may put in operation all the lines simultaneously, or else only one, or several lines separately, whereby the stage and stage scenery is deluged at the place where the fire burns.

The open sprinkler system is similar to, but perhaps more effective in action than the perforated pipe system. In some cases, large sizes of revolving sprinkling nozzles are fitted up and prove efficient fire extinguishers, if one could but rely on the water being turned on promptly.

The stages in many French and German theatres are protected by perforated pipe systems, whereas the English theatres have neither automatic sprinklers nor perforated pipes, because there being until quite recently no

*Details concerning the fitting up of a sprinkler system in theatres are omitted for want of space.

practical experience with the good results obtained by the former as in this country, they are considered unreliable, and also because the latter are looked upon as dangerous to property, although such an experienced fireman as Captain Shaw, of the London Fire Brigade, concedes that "such arrangements would make the safety of an audience, in case of fire, absolutely and completely certain."

One of the Munich Royal Theatres was the first German theatre to be fitted up on a large scale with perforated sprinkling pipes, and in this theatre, as well as in the large new Opera House at Frankfort-on-the-Main, what threatened to become serious conflagrations, have been put out by this apparatus.

The new Boston Fire Law requires "the proscenium opening of every theatre to be provided with a $2\frac{1}{2}$" perforated iron pipe or equivalent arrangement of automatic or open sprinklers, so constructed as to form, when in operation, a complete water curtain for the entire proscenium opening. There shall be for the rest of the stage a complete system of fire apparatus and perforated iron pipes, automatic or open sprinklers."

It seems unfortunate that this law should specify the perforated pipe to be of iron. It is well known that plain wrought iron pipe will soon rust, if kept dry and exposed to the atmosphere, and the perforations in the pipe would soon stop up with rust, dust, or sediment, and become inoperative.

The only available material for perforated pipe systems is brass, or better, copper pipe, and the systems installed in German theatres always consist of this material.

I do not know of any New York theatre fitted up with perforated pipes, whereas all the new theatres and many of the older ones have an automatic sprinkler system. Where requirements of economy do not prevent it, I should favor the installment, in addition to the automatic sprinkler system, of a perforated pipe at the stage side of the proscenium opening. This, when in action, would form an efficient water curtain and thus would be an additional protection of the fire proof iron or asbestos curtain, and thereby of the theatre audience in case of a stage fire.

(13) Fire Pails.

In addition to the automatic steam fire pump and the automatic sprinkler system, every theatre should be provided with a large number of fire pails or fire buckets. It is a well-known fact that more fires are put out annually by hand buckets than by any other fire extinguishing appliance. One bucket of water used at the proper moment during the first minutes of a fire just started is of more value than the largest fire pump half an hour later. Fire pails, therefore, constitute in theatres as in other buildings, the most useful and most effective of all interior non-automatic fire apparatus to subdue a local fire before the latter has gained any headway. Even in the hands of the most inexperienced employes such fire pails are of great protection and security.

Fire pails should not be kept on the floor where they are liable to be overturned, but should be either hung on hooks or placed on shelves. They should be marked "Fire Pails" or "For fire only," and should be distinguished by being painted a bright red color, to avoid their being used for other purposes and perhaps found missing or empty in case they are needed.

Fire pails must always be kept full of water, which evaporates rapidly. The practice of putting covers on fire pails to prevent evaporation is of doubtful expediency, as it renders the daily inspection of the fire pails more difficult. There should be a penalty enforced for the use of the fire pails for other purposes.*

As to the number of fire pails required for a theatre, it is usual in other buildings to estimate 5 pails for 5,000 sq. feet, or less, of area, and to add one pail for each additional 1,000 sq. feet, but for theatres, this allowance, at least for the stage, is hardly sufficient. The N. Y. Theatre Law requires four casks of water on the stage and at least two pails to each cask, making eight pails. There would, however, be no harm in doubling this allowance. The equipment of the Fifth Avenue Theatre comprised 48 galvanized iron fire pails and 18 insurance pails.

(14) Portable Fire Extinguishing Apparatus.

In addition to the hand fire buckets, it is desirable to have on the stage and in the auditorium a number of portable fire extinguishers. Sometimes common hand force pumps are used, but much better than these are the fire extinguishers working under pressure. Of these there are a great many types, which may be sub-divided into chemical and pneumatic extinguishers, the former being loaded with chemicals generating carbonic acid gas, while the latter are charged with compressed air.

The well known Babcock and the Champion Fire Extinguishers, both manufactured by the same firm, are examples of chemical fire extinguishers, and throw a commingled stream of water and carbonic acid gas. They are strongly made of heavy copper, in various sizes and capacities, ranging from a small portable hand apparatus to large chemical village engines. The copper cylinders of the apparatus hold a solution of bicarbonate of sodium in water and also a sealed bottle of sulphuric acid. By turning a hand wheel at the top of the extinguisher the bottle is broken and immediately the two fluids mix, generating carbonic acid gas.

The Harkness and the Miller Fire Extinguisher are examples of the pneumatic extinguishers. In these, the copper vessels hold a non-freezing, fire extinguishing liquid compound, and are charged with compressed air under a high pressure. By opening a lever cock the apparatus is put in operation, and no gas is generated until the liquid strikes the fire.

The advantage of the pneumatic extinguishers consist in their using no acids which often do much damage when the apparatus is in operation. They

*Details concerning suitable material and shape for fire pails omitted for want of space

are also safer and perhaps more easily handled than the chemical extinguishers.

(15) Water Supply for House Service.

The foregoing description of the fire protection equipment of a theatre makes no mention of the water service needed for the plumbing appliances in a theatre. Whatever is needed in this line should, in my judgment, be entirely separate from the fire service.

The plumbing in some of our modern theatres is quite elaborate, consisting of a number of toilet rooms for the use of the public, toilet rooms for the theatre manager, the stage employees, for the actors, actresses and supers., lavatories in all the actors' dressing rooms, house tanks and house pumps, hot water tanks, etc.

A detailed description of the plumbing work in theatres, however, must be omitted as my paper is already too long.

WHAT A WATER SUPPLY ENGINEER CAN DO IN THE FIRE DEPARTMENT.

BY

JAMES E. TRYON, Secretary Fire Commission, Detroit, Mich.

[Read June 15, 1894.]

Detroit, as far as my knowledge goes, is the only city in the United States where the Fire Department is charged with the duty of providing a water supply for fire extinguishing purposes, or more properly speaking, the hydrants and reservoirs from which water is obtained for the use of the engines. The various municipal departments are controlled by commissions and it was due to the doubtful phraseology of the acts creating the Fire and Water Commissions that the Fire Department took charge of the hydrants and reservoirs nearly twenty years since.

Detroit was settled upwards of two hundred years ago, in 1701, and its water works were first intended for distribution only. The first mains were 2-inch tamarack logs, succeeded later by 3-inch iron pipe and with these primitive conduits, connections for hydrants were first made, and long after pipes of greater diameter had superseded the earlier mains the original connections remained to remind us of how little water we required for fire purposes during the ancient regime.

The first triumphs achieved by the Fire Department were :

1 The taking out of all 3″ connections.

2 The removal of all hydrants with 2½″ openings.

3 The drainage of all hydrants so they would not freeze in winter.

The abandoment of 3″ connections was attended with much labor and patient research. Some of the earlier water works officials seemed to have been inveterate foes to records and statistical data and it was generally necessary to dig down and ascertain what was feeding a hydrant when a short supply at a fire led us to inquire as to the cause.

I think that one of every kind of hydrant that had been manufactured from that of Bartholomew up to the very latest had been planted in our streets in order that our experience in this regard might be of benefit to the future. There were gate and compression hydrants. Few were good and many poor. What was considered the best, a compression hydrant with a frost jacket, was selected and the others relegated to the scrap heap. And it is worthy of remark here to state that during the years that have sped it has been a ceaseless struggle to retain this uniformity in hydrants and while it has not been altogether successful, it has been the means of making the system as near perfect as possible. In the early days very little attention was paid to the matter of drainage for hydrants, its importance not being fully appreciated. Now, of 3,000 hydrants, less than 5 per cent. are not drained to the sewer, and they only because there are no sewers to drain them into.

If Water Works Engineers would resolve not to have a "dead end" in their system of distribution the supply for fire service would be greatly enhanced thereby. Detroit, I am sorry to say, has too many "dead ends." A hydrant is of no use at the end of a water main, but I have utilized them by adopting a plan of placing reservoirs there. For this purpose we use a tub having a capacity of 7,000 gallons. We run a feed pipe from the main into the tub and place a valve at the end of the pipe. The engine, having 7,000 gallons of water to start with is able to care for the majority of fires. The reservoir is of paramount importance in all cities as affording storage for water that can be used in case of fire. In the event of a break in the mains or the freezing of pipes in extreme weather the reservoir is always available. Should it ever be necessary to call in help from neighboring cities it is frequently found that connection cannot be made with hydrants because of the lack of a uniform thread, but the reservoir can always be relied upon.

Down town we use larger sized reservoirs, some of them being sewer shaped, with a holding capacity of 20,000 gallons. In our 500 reservoirs we have nearly 4,000,000 gallons of water stored. Some of our larger reservoirs have two valves or one very large valve and are capable of feeding two or three of the largest engines.

Hydrants are constantly examined by inspectors who open the valve and allow the water to run through short lengths of hose into the sewer. This serves to flush the pipe and get rid of the dead water which is very apt to cause the boiler of the engine to foam. By this inspection the induction and waste valves are found to be performing their functions and the parts are oiled and left in condition for instant service. In Detroit a fire hydrant is considered sacred, and street sprinklers, sewer diggers and others who have occasion to use water in the streets, are obliged to get their supply elsewhere. To those who know how easy it is for a hydrant to get out of order in the hands of a person inexperienced in its use, the utility of stringent regulations for the protection of the hydrant will be appreciated.

The old adage that there are tricks in all trades applies to the Fire Department, and I found early in my career that it was the fashionable thing when an engine had a short supply at a fire to lay it to a lack of water. There are few propositions which cannot be demonstrated either by logic or mathematics, and when the conditions were favorable to a bountiful supply, I could only solve the problem on the basis of a fire engine out of order. Hence I was invariably skeptical when confronted with a condition which I could only persuade myself was a theory. Finally I proposed to the Master Mechanic of the department that we place a combination gauge on the inlet of the engine. If the machine ran away from her water a vacuum pressure would be recorded, otherwise the hydraulic pressure would be shown while the engine was working. The scheme was eminently successful and we have since had no complaints about poor water that could not be substantiated.

Take the matter of poor water at fires for instance; I will cite two for the purpose of showing what may happen in water supply engineering: In April, 1893, a fire occurred in one of the buildings forming a part of the plant of a

large brewing company in Detroit. The fire was quite ugly at the outset, and the officer in command promptly sent in a third alarm. When I arrived on the ground three engineers whose engines were located on Jefferson Avenue, in which was a 42″ supply main with a 6″ distributing main alongside, complained of poor water and proved it by recording a vacuum pressure on their combination gauges. It did not need the gauge, however, to tell the story, as by standing next the hydrant I could hear the suction. I could only think of a broken gate somewhere on the line, but when my friend, the Engineer of the Water Works, got my interrogatory and set about investigating, he developed one of the most serious minor defects in our system. It appears to have been the practice heretofore to lay large and small supply mains through districts they were intended to supply without connecting them to cross lines. In this case the engines actually pumped dry a section covering 10,368 square feet, and the investigation revealed that while the 42″ and 6″ mains were laid parallel they were only connected at points 5,100 feet apart, and that the district north was supplied entirely from this 6″ main, and all hydrants were connected with it.

In March, 1894, a fire occurred on Michigan Avenue and the following is the water supply record as submitted to the Engineer of the Water Works. Engine No. 3 took suction at the N. W. corner of 6th and Michigan Avenue :

Water pressure on engine when No. 8 was working	44
Pressure on combination gauge at same time	0
Pressure on engine when at rest	30
Feet of hose (3-inch) worked through	350
Lines of hose	1
Size of nozzle	1½″

Engine No. 8 took suction at S. W. corner of Baker Street and Michigan Avenue :

Water pressure on engine when No. 3 was working	80
Pressure on combination gauge at same time	15″ vacuum
Pressure on engine when at rest	27
Feet of hose (2½-inch) worked through	500

No. of lines, 2 ; length, 200 and 300 feet.
Size of nozzle on 200 feet, 1¼″ ; on 300 feet, 1⅜″.

No. 3 shut down first—No. 8 had both nozzles open about 10 minutes. Hydrant did not properly supply both lines and the 1⅜ nozzle was shut off. The water pressure on engine then jumped up to 170 pounds, with 10 pounds on the combination gauge at the same time."

The supply in this case was an 8″ main, the hydrant being on 4-inch mains one just north and the other just south of the 8″. An investigation revealed that the following conditions existed :

The gate on the north side of Michigan Avenue was closed, so that engine No. 3 was pumping out a 4″ pipe having a feed from but one way, and that from a 3″ pipe. This was in a section which has been built up a great many years and the pipeage is as old as the locality. Even had not the gate been

closed the pipeage was not sufficient to feed the large engines, as was shown in the case of No. 8. With one $1\frac{1}{4}$" stream they were all right, but when they came to add a $1\frac{3}{8}$" stream they were lost.

Here was a positive demonstration that a 4" hydrant on a 4" main was of no use when big streams were required.

To return to the combination gauge on the inlet of the engine. If I go to a fire and see a feeble little stream that we should only expect to escape from the pipe of a lawn hose, I follow the line back to see where it comes from. If the gauge shows any pressure I ask the engineer to "let her out" and see how much the pressure can be run down. If running at his maximum speed the pressure is still maintained I know the water supply is not to blame for that little stream. The trouble is with the engine. If, on the other hand, the gauge runs down to a vacuum pressure I begin my work to locate the trouble. The first thing, of course, conceding that the hydrant is equal to the occasion, is to look for broken and shut off gates, and locate the feeders to this particular main. Former Superintendents of Construction, as I have shown, had a bad habit of running cross lines without connecting them and this omission is the most frequent cause of a poor supply for fire extinguishing purposes. We have in use 6", $4\frac{1}{2}$" and 4" hydrants, and I find in practice that the difference between the hydrostatic and the hydraulic pressures is in the case of the 4" hydrant 35 per cent. and with the $4\frac{1}{2}$" 26 per cent. This test was made with an ordinary engine, capacity 500 gallons per minute, working through a length of $2\frac{1}{2}$-inch hose with a $1\frac{1}{8}$ nozzle, the static head being 17 pounds. For each additional length of hose deduct 2 per cent.

The evolution of the modern fire engine with its pumping capacity of 1,200 gallons per minute, the introduction of 3" hose and $1\frac{1}{2}$" nozzle held by the "iron man," as the fireman terms the hose-holder, has given the fire service the opportunity of throwing big streams of water; solid streams that do not break until they reach the fire and which leave a black mark where they strike. But they have shattered the idols of Water Supply Engineers, who have clung to the four-inch hydrant as being plenty large enough. Some things come to us when we least expect them with stunning force, and when we recover from the blow we wonder we were not hit sooner for clinging to the idiotic notion that what we could do in the 80's could be done in the 90's. Yesterday is no relation of tomorrow. I well remember we had a fire a few years ago in one of our finest residence districts. The fire was in a Church edifice in process of construction, and it burned so fiercely that a second alarm was sent in. Up to that time I had held tenaciously to the idea that a hydrant at every corner was sufficient, but on this occasion I learned that it was not, some engines having to stretch 1,000 feet of hose. I could not shield myself behind the belief that no one ever thought a second alarm would be sent in from that district. It had been, and what had occurred might be repeated any day or night. The answer to this problem was: More hydrants are needed, and plant them in the centre of blocks as well as on the corners. So it was with the 4" hydrants which might be expected to serve the large engines. They would not do it and the only recourse was to

take them out. In reaching this conclusion I made some experiments, the results of which are herewith given:

In January, 1893, at the burning of the High School building, one of our largest Amoskeag engines (No. 3) was located at a 4″ hydrant, the branch and feed pipe being of the same diameter. The main was a 6″ and connected within 500 feet with a 30″ supply main. The static head at that point at that time was 28 pounds. The number of engines employed at the fire was 6. On this occasion No. 3 had out two lines of 600 feet, 300 each, of 3″ hose with a 1½″ and 1¼″ nozzle and with plenty of steam could only get 100 pounds of water pressure without registering a vacuum pressure.

In order to furnish data for this paper, I had a test made on June 9th, 1894, at the same hydrant with these results:

Engine No. 3, first size Amoskeag, capacity 1,200 gallons per minute.

Pressure at hydrant, engine at rest ..... 28 pounds

400 feet of 3″ hose, 1½″ nozzle.

Steam pressure ..... 120 "
Water pressure ..... 160 "
Combination gauge pressure 0

350 feet 3″ hose, 1½″ nozzle.

Steam pressure ..... 120 pounds
Water pressure ..... 160 "
Combination gauge pressure ..... 10″ vacuum

400 feet 3″ hose, two lines 200 feet each, 1½″ nozzle.

Steam pressure ..... 120 pounds
Water pressure ..... 40 "
Combination gauge pressure ..... 20″ vacuum

The engine was then moved to another location and connection made with a 6″ hydrant fed by 36 feet of 8″ pipe with 8″ branch on a 30″ main.

400 feet 3″ hose, 2 lines 200 feet each, 1½″ nozzle.

Steam pressure ..... 100 to 65 pounds
Water pressure ..... 80 "
Combination gauge pressure ..... 15 "

No. 1 engine (same size, Amoskeag) was then called and this result obtained.

400 feet 3″ hose, 2 lines of 200 feet each, 1½″ nozzle.

Steam pressure ..... 100 to 45 pounds
Water pressure ..... 120 "
Combination gauge pressure ..... 8 "

Both engines were worked at their maximum speed, greater perhaps than would ever be required at a fire, but in order that the best results could be secured.

In my judgment the utility of this test is the demonstration that whereas the 4″ hydrant can be relied upon to supply one good stream, it cannot furnish two. At a fire, if the Chief of the Department demands more water or

orders two lines from one engine, there should be no excuse that the hydrant will not supply them.

After each fire I receive a report of the condition of the water supply which shows:

1 Location.
2 Whether hydrant or reservoir was used, and the condition it was in when left.
3 Pressure at the engine while at work.
4 Pressure on the combination gauge at the same time and while the other engines were working.
5 Pressure on the engine when at rest.
6 Number of feet of hose worked through, and the number of lines.
7 Size of nozzle used.
8 Time worked.

Correct answers to these questions will show the character of the streams furnished. Copies of these reports are forwarded to the Engineer of the Water Works for his information and the benefit of both departments. For a fire of any magnitude these results are tabulated, and if there is a deficiency in the supply the weak spot is located if possible.

The ruling passion of the majority of Engineers of fire engines is "pressure." Frequently more water than is required is forced through the hose and poured into some insignificant building that happens to be on fire. But in the case of a sweeping fire, when powerful streams are worth gold mines, how often do we see firemen working through 800 feet of hose when half that length would be ample. I hope the day will come when all Fire Departments can afford to have an officer on the ground at all large fires who shall be clothed with sufficient authority to see that if too much hose has been laid out on the first stretch the line is broken and the surplus thrown out and that for the ordinary stretch of 300 feet of hose all that is required at the big fires in the business district where hydrants are plenty, not to exceed 100 pounds pressure is observable at the engine. It frequently happens that much of the energy of a steam fire engine is wasted because of the lack of judgment displayed by those having it in charge. The superior officer at a fire is too busy generally to look after such details as these and they are usually allowed to go by default. A short time ago I saw three engines serving a water tower working at a fire where the huge stream that was really required was broken and uneven in its delivery. Going about to the different engines I found that one had out a line of 3" and two had 2½" hose; that one had 240 pounds water pressure, another 180, and the third 140, and that the three lines of hose were practically of the same length. Here was the work of the water tower practically nullified because of the absence of some one with the knowledge and power to regulate the work of the engines.

The Detroit pipe lines laid for the purpose of making the fire boat available for fires at least one-half a mile distant from the river were planned by, and laid under the supervision of the compiler of this paper, and a brief descrip-

tion of them may not be out of place. These lines consist of three long lines 2,000 feet each, and three short lines of 1,000 feet each, or 9,000 feet in all. For these lines the 8″ steel pipe, such as the Standard Oil Company uses for piping crude oil from the oil fields to tide water, was selected. The pipe had been subjected to a test of 1,000 pounds hydraulic pressure. Connection at the river is made with a 3 or 5-way siamese, with $3\frac{1}{2}$″ openings, with a clack valve over each to enable the boat to start its pumps as soon as the first connection is made. Hydrants having two 3″ and one 4″ openings are set at intervals along the line with a manhole opposite each. At the end of the pipe is an air valve loaded to remain open until the water comes, and a relief valve set at 250 pounds, which will open when the pipe is filled and the recoil renders it necessary for something to give way.

We have worked through 1,000 feet of 3″ hose, stretched from a hydrant 2,000 feet from the river, with a pressure of 165 pounds at the hydrant. These results were obtained with a pressure of 175 pounds at the boat. The friction loss in a line 2,000 feet long working through two lines 100 feet each of 3″ hose is as follows:

Two $1\frac{3}{4}$ Inch Streams.		
Pressure at Boat.	Pressure at Hydrant.	Loss per Feet.
120	80	.0002
140	90	.0025
160	105	.0275
180	120	.0003

These lines were fully completed during the summer of 1893, and were filled repeatedly during the past winter. We have had but two incidents to mar the successful working of this branch, one being the failure of the air valve to work, owing to the insufficient load, which made it impossible to fill the pipe, and the other was due to the failure of a relief valve to work, having been set at 400 pounds. The damage in this case was the blowing off of the siamese. The pipes are laid as nearly on a true grade as possible, the rise being about $8\frac{1}{2}$ feet in 1,000. The grade is toward the river, and to prevent the freezing of the dead water, the pipes are emptied after each filling. When the boat responds to an alarm of fire, connection is made with the most available pipe line, and the pumps started just as a land engine fills its line of hose. When the pipe is filled the pumps are stopped to await orders. A single wire laid in a pipe, in the same trench with the pipe, is run into the engine room and a signal code is used. By means of a push button, which can be operated at any hydrant on the line, the boat is signalled by the use of the following code:

1 Bell..... Start pumps
2 " ..... Stop pumps.
3 " .....20 pounds less pressure
4 " .....20 pounds more pressure
6 " .....Pick up

In this way the pipe line enables the boat to play its part in the work of extinguishing the fires that may occur in the city of Detroit.

The burning of the great dry goods store of Edson Moore & Co., in November, 1893, was without doubt the most disastrous fire that ever occurred in our city. The flames were first discovered on the fifth or upper floor of the building occupied by this firm. The fire originated by a lighted cigar stub communicating with a bale of cotton batting; the fire then jumping from one bale to another with as much rapidity as it ignites the impalpable dust of a flour mill.

When the alarm was given for this fire the flames were bursting through the roof, and before a stream of water could be directed into the building the roof had fallen and the inclosing walls had begun to fall. The fire boat "Detroiter" responded to this alarm and by means of the pipe line sent four $1\frac{3}{4}$ and one 2" streams into the burning structure. These streams were of the kind which make a black mark wherever they strike. Men who are accustomed to attend fires unite in the belief that but for the big streams thrown by the Detroiter there is no telling where the fire would have stopped. In one and a half hours the immense building was a heap of smouldering ruins, and the fire had not only been confined to the building where it originated, but it had been prevented from crossing a 20-foot alley and communicating with one of the greatest chewing tobacco factories in the West. And the secret of it all is that the pipe line enabled the boat to deliver these immense streams that made the craft equal to a dozen steamers of the largest size.

At the Edson Moore & Co. fire, above mentioned, the falling of inclosing walls early in the fire suggested the question, what would be done with the pipe line in the event of the demolition of a hydrant. There was but one course open, and that was to shut down the pumps, dig away the debris and plug the broken part. This would take time. This problem had not suggested itself when the line was planned and it needed experience, the best of all teachers, to demonstrate the necessity of solving it. The solution was reached by providing for a dividing gate, by which the hydrant or the main could be shut off. One of these was placed in every manhole, except the upper one, so that in the event of a break it is possible to shut off a section of the pipe line without any stoppage at the boat. I do not know that any statement of the work of the pipe line would be of interest. In fact, since I told some gentlemen of our throwing a $1\frac{3}{4}$" stream horizontally 484 feet and saw the look of polite incredulity that came over their faces, I have been very chary about speaking of results. But I can say that we gave the Boston aldermen an idea of what six $1\frac{3}{4}$" streams looked like 2,000 feet distant from the river. And a short time prior to that occasion we gave some Boston gentlemen an exhibition of a $2\frac{1}{2}$" stream, two lines of 3" hose, 100 feet each being siamesed into one length of 50 feet of $3\frac{1}{2}$" with 120 pounds hydrant pressure with the water flowing. We have had three $1\frac{3}{4}$" streams flowing through 100 feet lengths from hydrants one block apart, the gauge showing 100 at the lower and 95 pounds at each of the upper hydrants.

The successful fire fighting of the future must be done by big streams. The underwriters cannot survive many years like 1893, when nearly $200,000,000 was paid out in fire losses. The placing of risks on the basis of the moral hazard or the adjustment of rates in accordance with the conditions of the physical hazard will not cut as much of a figure as the question of underwriters engineering, which will contemplate the handling of these large fires and their confinement to the building where they had their origin. We must recognize the fact that the logic of events has already taught us that as the country grows the number of fires will augment and the value of property destroyed be correspondingly increased. Take my own City of Detroit, for instance, and we find that whereas there were 128 alarms in 1872, there were 752 alarms in 1892, or a fraction less than 500 per cent. increase in 20 years.

Take the City of Chicago, theatre of the greatest fires of modern times, and we find that in 1893 there were 1,675 more actual fires than in 1892, an increase of nearly 50 per cent. Increasing at that ratio would mean 33,500 more fires in 1913 than occurred in 1893. It is not the purpose of this paper to deal with the cause of fires, but rather with how to put them out. They are always with you and when you least expect them the alarm tells you they need your attention. In my judgment there is no branch of engineering that is more in need of being pushed than that of water supply for fire extinguishing purposes. We read occasionally a newspaper account of a big fire and see that a second then a third and then a special alarm was sent in and then that 20 or 30 steamers were playing on the fire. The question that the Water Supply Engineer asks of himself on such occasions is "were they all supplied?"

Who of us, in planning for the destructive conflagrations that must come to all cities, think of what it means to provide a supply for 30 engines? Those of us who think of this problem over the drafting table or in the field when there are no signs of fire must pause at times and think what a supply for 30 steamers means. Chief Sweenie, of Chicago, told me not long ago that he could place 55 engines around the store of Marshall Field & Co., and no one of them would be obliged to stretch more than 500 feet of hose. I have provided a supply for 30 engines in Detroit, all working through short lines of hose, by placing double hydrants with 6″ valves and 8″ feed pipes on large supply mains. In Fire Departments, as in all other branches of science and art, there is a disposition to enlarge. Each fire has its lesson and brings the demand for apparatus of greater power. So while the events of today are in the minds of the Underwriters and the Fire Chief, the Water Supply Engineer is dealing with the future. He must be planning for the work that is to come, perhaps after he has laid aside the thoughts and burdens of life and sailed out upon the unknown sea that rolls around the world.

And that, Mr. Chairman and gentlemen of the Convention, is what a Water Supply Engineer can do in the Fire Department.

We may not live to see the improvements that must come in the fire service, but I venture the prediction that a future generation will see fire engines in two parts, pump and boiler, operated and propelled, possibly, by electricity, with a lifting capacity of 5,000 gallons per minute. We think 3″

hose is too heavy now, but 4" will eventually replace it, and 2½" streams will be the correct size for effective ground work.

There is a tradition that the King of France once asked the grim Cardinal Richelieu how he proposed to feed all the soldiers he saw marching out of Paris, and the reply was "Sire, that is the enemies' affair."

How are we to supply these ponderous fire fighting machines? That is the business of the Water Supply Engineers of today.

LAYING A SIXTEEN-INCH MAIN ACROSS A ROCKY MILL STREAM AND OVER A DAM.

BY

GEO. F. CHACE, Superintendent, Taunton, Mass.

[Read June 14, 1894.]

Last year the Taunton Water Works, on one of the principal streets, took up 2,441 feet of 6-inch pipe and replaced it with 16-inch.

By laying a 2-inch temporary pipe along the sidewalk curb and connecting with each service and with hydrants at either end of a 1,000-foot section, it was a comparatively simple matter to make this change and keep the consumers along the line supplied with water. One part of the line, however, presented some difficulties. The original 6-inch pipe was laid underneath the bed of a mill stream called Mill River, crossed by the street a short distance below the dam.

The work had been troublesome and costly as the bed of the stream was full of rocks and much blasting had been necessary. The distance between the stone abutments of the bridge is 60 feet. In February, 1886, a severe freshet destroyed the wooden bridge which was there at that time. An iron truss bridge took its place, set higher than the old bridge, with much better abutments and improved water way. One hundred and forty-six feet beyond this bridge was a flume 30 feet wide This flume is still spanned by a wooden bridge. The original 6-inch pipe was laid under the bed of both of these streams and through the wing wall of the dam, an end of which meets the highway between the two bridges.

Under these conditions, to take up the 6-inch for a distance of 236 feet and replace it in the old ditch with 16-inch would be a serious undertaking. The manufacturers who owned the dam very properly objected to the risk of making a leak through the wing wall of their dam. Having in mind the recent disaster at Portland, where the break seems to be fairly attributable to the piercing of a part of the dam by a 10-inch pipe, I was myself wholly unwilling to assume the responsibility of undertaking to make the passage of the 16-inch pipe through the wing of this dam infallibly tight against leakage around the line of its direction through the wall.

It was impracticable to lay the pipe over the bridge, for it is crossed by an electric railroad, and neither the driveways nor the foot paths over the bridges could spare the room for the pipe. It was impracticable to suspend the pipe beneath the bridges, because, in time of spring freshets, it would obstruct the free passage of the water.

Moreover, 236 feet seemed to me too great a length of pipe to expose to the winter air.

Any method of suspending at the side of the bridges involved carrying the pipe along between them exposed to the air for 146 feet, or burying it and laying it through the wing of the dam.

After careful consideration of all the circumstances, the following plan was finally adopted. The Taunton Locomotive Manufacturing Company was given the contract to make 16-inch flange pipe, laid with a truss on the up stream side of the bridge with about a 60 foot span, the company to make the pipe and truss and place the same in position.

The walls on either side of the stream were built up a foot or two to bring the pipe just above the level of the floor of the bridge. The truss was made of inch and a half wrought iron bolted to lugs at each end, and with two substantial truss pillars. There was nothing unusual about the form of the truss. At one extremity, an eighth bend, with flange at one end and spigot at the other, was calked and bolted to the bell and spigot pipe which descended into the ground, the change of grade being accomplished by two eighth bends, one on the surface and the other joined to the pipe laid five and a half feet below the surface, the whole being firmly bolted together. At the other end, owing to a bend in the street, was a special curve with an angle of 165°, or 15° deflection.

The fence railing of the bridge was temporarily removed, the joints bolted together, the truss put on, and by means of bars and falls the whole length was rolled over into place.

Between this first bridge and the second one was a stone wall along the bank of the stream, the top of the wall being 10 or 12 feet above the bed of the river. On this wall was a picket fence bolted to the wall and braced on the outside with iron braces set into projecting stone wings. There was no room for the pipe on the wall, inside or outside the fence. With the consent of the superintendent of streets, I had this fence removed and the surface of the wall leveled and pointed up. I then had the pipe laid along this wall in the following manner. A floor of 2-inch tongued and grooved plank was laid upon the wall. This floor was made twenty-two (22) inches wide. Back of each bell, of the bell and spigot pipe here laid, was a support cut the shape of the pipe out of three inch plank set edgewise, suspending the pipe about three inches above the wooden floor.

After the joints had been calked, the pipe was boxed up with 2-inch plank matched and planed, the box being thoroughly packed around the pipe with mineral wool, there being from two to three inches space all around for this purpose. The side of the box next to the street was carried up to a height of five feet and formed a fence. Then an incline of 2-inch plank, matched and planed, was built like the side of a pitch roof about a foot below the top of this fence and projecting a few inches beyond the top of the river side of the box. The space between the horizontal top of the box and this sloping roof was left filled with air. Then the whole structure was painted. Bell and spigot pipe was carried across the flume on the up stream side supported by a common iron truss. Descent from this was made into the ground by one-

eighth bends, and the whole was made secure by being collared and bolted together.

The accompanying photographs give a clearer idea of the situation than any word description.

The old 6-inch under the bed of the stream and between the bridges was disconnected at each end and left undisturbed.

Two sections, one 60, and the other 30 feet long, are exposed to the weather. It is our experience in Taunton that with a constant circulation comparatively short lengths of mains may be exposed without danger of freezing. I think there is a tendancy to an expansion in summer which makes it necessary to watch the joints of bell and spigot pipe and occasionally retouch them. I did not dare to try the experiment of exposing so great a length as 236 feet.

The plan here adopted may not have been the best possible; in my judgment, it was, on the whole, the best for all the surrounding circumstances, and the very purpose of this paper is to provoke discussion as to the proper method to pursue in such a case.

DISCUSSION.

MR. HOLDEN. I would like to inquire of Mr. Chace why he did not put in an expansion joint to provide for the expansion which he is liable to have.

MR. CHACE. Simply because I did not think it was necessary, judging from the experience we have had with a pipe over a bridge in Taunton, where there never has been sufficient expansion to cause a serious leak; it has simply sweat a little once in a while. It was to save expense, that is all.

MR. HOLDEN. I laid a 12-inch line over a bridge some 700 feet long, and in order to guard against any leaks I put in two expansion joints. The pipe was laid in August, in hot weather, and I noticed in the winter, when the temperature was down to about zero, there was a contraction of some six or seven inches, or nearly an inch to every 100 feet, but I never have had any leaks or any trouble from it. The joints have expanded and contracted with the weather.

MR. CHACE. I think I should certainly put an expansion joint on 700 feet of pipe.

MR. BRACKETT. It does not appear to me that there is any necessity for providing expansion joints for cast iron pipe laid with lead joints on bridges.

The cast iron pipe, when in service, must have nearly the same temperature as the water which it carries, and the temperature of the pipe cannot be very different whether laid on a bridge or in the ground. Pond and river water has a variation in temperature between 32° in winter and 72° in summer or 40° F.

The increase in length of a cast iron bar 100 feet long due to a change of 40° in temperature would be .025 feet, or about $\frac{1}{4}$ of an inch. In the case of a line of cast iron pipe this change in length would be distributed over eight joints and could not cause any trouble. We have in Boston a number of lines on bridges from 200 to 900 feet in length, which have no expansion joints and have never experienced any difficulty.

THE CARE OF A WATER METER.

BY

J. C. WHITNEY, Water Registrar, Newton, Mass.

[June 15th, 1894.]

The care of a water meter begins when that meter has been received from the factory, and the first attention required is a careful test as to its performance on both large and small flows.

Probably the meter has previously been examined by the maker and found to be accurate, but it is important that each department should make its own tests, not only to insure accuracy, but also to have a record which can be produced in case the registration of a meter is doubted by a water taker.

It is suggested that the first test in case of a $\frac{5}{8}$" meter consist in running five feet at the rate per minute stated by the maker to be the greatest proper quantity. On this stream the variation from absolute accuracy should not exceed 2 per cent either way.

The results obtained from carefully running five feet are as satisfactory as from double that quantity, and the test takes less time and water.

On small streams it is a question as to the rate of the flow on which the meters should be tried ; but perhaps a rate slightly in excess of one foot per hour, say 1 2-10 feet, would be satisfactory. The quantity of water run at this rate need not be more than one foot, and probably somewhat less than this would answer, the meter being expected to indicate at least 80 per cent of the flow. In this second test, time can be saved by connecting several and running together. This trial on small streams is also of advantage on account of the full water pressure being on the meters, thus showing any leaks in the packing which exist and perhaps saving a trip to stop an annoying drip in a house cellar.

The record of tests is to be recorded in something like the following form—name of meter, pattern, size, number of years in use, amount registered to date, length of test in minutes, size of orifice, number of feet run, weight of water in lbs., percentage registered, reading of meter at begining and end of test, and the date of testing.

The meter is then put in service and is entered in a record book having following headings—in ink, the name of meter, number of size, when set ; in pencil, name of taker, street and number, approximate water pressure, and amount registered to date ; following these are fifteen columns each for a year in which is to be recorded the nature and cost of any repairs found necessary. The items, water taker, street and pressure are in pencil so they can be readily changed in case the meter is reset. The record is to be made up to date annually if possible.

From this tabulation may be derived the average age, average amount registered, cost of repairs per meter and cost of repairs per 100,000 cubic feet registered, and will show quite accurately the work which is being done by each of the various kinds in use.

After being set, the meter should be read as often as once a quarter. There are some advantages in monthly readings but the extra expense, which such frequent readings entail probably outweigh the benefits.

In works having a large number of meters, it is advisable to have an inspection book for each ward or district, partly that the book may be of convenient size and partly that the office work of figuring and posting may be carried on at the same time. Each book, when turned in is to be examined and a record made of cases where registration was either larger or smaller than usual, and a second reading taken.

At least once in two years, a special examination should be made as to the accuracy of the meters in use in the system. The examiner is to be provided with a large pail – capacity about four gallons—and two brass caps, one having an orifice of $\frac{1}{20}$" diameter, and the other $\frac{1}{4}$". Starting in a street, the first five or six houses are notified to use no water for half an hour; after assuring himself that no water is being run on the premises, the meter is read, cap with $\frac{1}{4}$" orifice is attached to faucet and $7\frac{1}{2}$ gallons run, the pail being filled twice. The meter is again read and discrepancy noted. The $\frac{1}{4}$" cap is then disconnected, the $\frac{1}{20}$" attached, water turned on, and meter watched; if it does not start within a minute on this stream the examiner notes it and the meter is taken out for repairs as soon as convenient. If it has started properly it is allowed to run $1\frac{1}{2}$ gallons, which on our maximum pressure takes about three minutes, Ordinary cases can be detected in this way—doubtful ones may be taken out for more thorough examination.

DISCUSSION.

Mr. Hodgson. I am afraid it may seem presumptuous for one who has so recently come among you, to attempt to say anything. But I desire to express my approval of what Mr. Whitney has said, as it presents a scheme approximating somewhat nearly to the English and European conditions, where the meters, I believe, are better taken care of than they are on this side of the water at the present time. The recommendation of stated periods for the examination of meters, seems to me deserving of particular consideration. I think it will be admitted that in order to insure a more widespread adoption of meters the first essential is that the general public should have confidence in the meter as a meter, that it should no longer be the subject of jokes more or less appropriately applied. The practice on the other side is that within a stated period the meter is changed, taken out and renewed and a new meter substituted. That method is very much facilitated there by the fact, that in Europe generally, the meters are the property of the water selling authorities, and do not belong to the consumer. The water selling authority, therefore, has full control over the meter. There might be some little difficulty on this side on account of the water-takers owning the meters, and Mr. Whitney's

suggestion of an examination on the spot, I think, would answer very well here where the cost of labor for removing the meters would be more serious than in Europe where the labor is cheap. I certainly think Mr. Whitney's suggestion is worthy of trial. There are a large number of different types of meters in use in this country, and the period of the stated examination would vary, but I think each city, according to the quality of its water and the nature of the work, would arrive at a knowledge of the proper period for the inspection which Mr. Whitney suggests.

Mr. Milne. Mr. President and gentlemen of the New England Water Works Association: am very glad to meet you here. I am very much interested in your association as I am in other similar associations; I know you do not meet in the spirit of rivalry, but rather in the spirit of emulation. We come here and bring our thoughts and our experiences, compare notes, run up against each other and find out what we know, and sometimes we learn that the more we know the less we know. Indeed, that is the way most of us feel, that the longer we have been the in line of this work the less we know.

Now, regarding the subject of meters, it is an old subject to many of us, and yet it is ever new, it is always involving new questions, new thoughts, new ideas which are brought out by practice, observation and experience. I believe' as has been stated here in this meeting, that meters should be the property of the municipality or private water works corporation. I believe they should be as much so as the pump plant, as the hydrants, as the fire service, as the water distribution pipes. And why not? If it is the property of the corporation you have greater jurisdiction over the same, your legal status is better established, and the people feel better about it, too. There is a great deal of friction occasioned among the water-taking population when you impose meter restrictions upon them for the very reason of the price of putting in and maintaining a meter. In my judgment that expense should be assumed by the water company or by the municipal administration in charge of the water works. And that thought is happily prevailing among the water works men of this country who are finding by experience that it is better that the water meters should be a portion of the plant.

Regarding the care, the testing and maintaining of the meter system, the success of that is largely dependent upon the character of the superintendent or the person in charge. If you have a good engineer in charge of your pumps you have good pump service; if you have a good superintendent or engineer in charge of your meter system you are going to have a good meter development. A great deal of care should be used initially in the setting of meters. Frost, low temperature, is one of the most destructive agents of water meters, and I am astonished at the carelessness exhibited by what I read in the water works reports about frozen meters, and meters having to be taken out for repairs frequently. In nine cases out of ten the meter repairs are largely due to the carelessness of the administration. That is my experience. Gentlemen, I am very glad to meet you, and I hope that at Indianapolis we shall have a fair representation of the New England Water Works Association.

NOTES ON EUROPEAN WATER SUPPLIES.*

BY

ALLEN HAZEN.

[Read Dec. 12th, 1894.]

It has been my good fortune during the past year to visit a large number of the leading water works in Central and Western Europe, and I propose to give you this afternoon, not a systematic or exhaustive account of them, but simply to mention some of the points which have specially interested me, and which I trust may also prove of interest to you.

The question of securing an adequate supply of pure water is by no means confined to the western hemisphere, and the activity with which projects are being discussed and carried out in European capitals was a constant source of surprise to me, as we are apt to think of European cities as of slower growth and more fixed habits where public works would progress more slowly.

In London a royal commission has just been considering the question of the probable needs of the eleven millions of people which they estimate London will contain in 1931.

Birmingham is just commencing the construction of an aqueduct which is to supply it with pure mountain water from Wales, and on the Continent Brussels is considering the project for a water supply for the greater metropolis which they propose to form out of the city and its suburbs.

Hamburg completed last year the filters which had been so long contemplated, and the construction of which was hastened by the awful epidemic of cholera which ravished the city in 1892. Berlin is also largely extending its works. In Vienna the supply of mountain spring water has recently been increased, and still other projects of much greater magnitude are being considered for the supply, both of the central city and of the surrounding towns. Paris, which had so long suffered from the lack of an adequate quantity of water for domestic purposes, completed in 1892, an additional spring water supply, with a minimum yield of 23,000,000 gallons, and still greater projects are now being discussed for execution as soon as the needs of the population exceed the present supply.

In all of these schemes there is one striking difference from corresponding projects in America. The quantity of water provided per head is always less than one-half, and frequently not more than one quarter, of the supplies considered necessary for American communities. The causes of this difference are not altogether clear. In some instances the small European consumption may be, in a measure, attributed to a smaller proportion of water closets, or to the fact that the entire population do not have flowing water in their

*This paper was first read before the Boston Society of Civil Engineers, Nov. 17, 1894.

own apartments. But after making all possible allowance there still is a wide discrepancy which cannot be accounted for by the greater comforts or cleanliness of the American cities. The fire protection is upon a radically different basis from that in America. In all European capitals the construction of other than fireproof buildings is strictly prohibited, and fires, as we understand them in America, can hardly be said to exist. In Berlin during the past year the quantity of water which supplied all the necessities of the fire department for extinguishing fires and other purposes was less than 3,000 gallons daily and in no other German city, except Hamburg, was so large a quantity required.

American water pipes are planned throughout to allow a concentration of water for fire purposes. European water pipes serve only for the distribution of water for domestic purposes, and there is no provision, or, if any, only of a most rudimentary character, for the concentration of large volumes of water necessary for extinguishing the fires which are of almost daily occurrence in American cities. The decreased sizes of the pipes which this system allows, no doubt reduces the leakage from imperfect joints, and at the same time, by greatly decreasing the cost, allows more attention to be given to the quality of the work.

Another element which, in Europe more than in America, tends to restrict the use of water, is the use of meters. In German cities, particularly, it is often the case that no water is sold except by meter, and in Berlin over 86 per cent. of all the water pumped is actually accounted and paid for, leaving less than 14 per cent. for use for all public purposes, street sprinkling, public fountains, sewer flushing, etc., as well as for waste. The smaller quantity of water required allows, in many ways, more attention to be given to quality, and the study of the qualities of the water supplies has received a new impetus since the cholera epidemic of Hamburg two years ago. This epidemic, as you remember, caused the death of 8,000 people in Hamburg in less than a month, while the neighboring cities of Altona, Harburg and Wandsbeck remained substantially free. The water supply of Hamburg at that time was drawn unfiltered from the river Elbe, from a point slightly above the city, but where it was subjected to the occasional pollution from Hamburg's own sewage, as well as to the constant but more remote pollution from the 50 cities, each with 20,000 inhabitants or more, upon the river and its tributaries, and with an aggregate population of about 6,000,000. The water shed of the Elbe above Hamburg has an area of about 52,000 square miles, and the annual rainfall is 28 inches.

The other cities mentioned had other and better supplies, and their escape from the cholera was attributed by the Imperial Board of Health, after a most thorough examination, to this fact. Since that time Hamburg has pushed to completion, at a cost of $2,300,000, the filters which were previously projected, and, at the present time, has one of the finest water supplies of Germany. The effect of this Hamburg-Altona incident was not confined to the local conditions, but has resulted in many radical changes throughout the German Empire. Two years ago Hamburg was the only city in Germany drink-

ing unfiltered surface water, but there were a number of other cities, Stettin, Lubeck, and others, which filtered their waters at high rates and under conditions other than those found most favorable where filtration has been most carefully considered. Probably as a result of their investigations at Hamburg and Altona, the Imperial Board of Health issued an order prohibiting the use of unfiltered surface waters for drinking in any German city, and in those cases where filtration is employed, prescribing the conditions under which such filtration should be executed. They prescribed, for instance, the rate of filtration, the minimum depth of the filtering medium, the way in which filters should be treated at the times of cleaning, and they also suggested that the effluent from each single filter should be examined bacterially every day by some officer appointed by the city, and, if possible, permanently connected with the water works. Some of these rules were objected to by the water works engineers, on the ground that they could not be carried out without too seriously upsetting existing arrangements. Afterwards a conference was arranged between the board of health and a committee selected by a permanent society of water works engineers, (Deutscher Verein von Gas und Wasserfachmanner) and a new set of rules, differing somewhat in detail from the first ones, were prepared, and these rules have since been issued by the Minister of the Interior, and are considered as binding upon all German water works. In accordance with them the water works which had filters which were not capable of conforming to the requirements, have, in every case, so far as I know, during the past year, reconstructed their works in a more or less thorough manner to meet the requirements, and the examination of water bacterially was commenced in most cases with the first of April, 1894. In this connection I may say that the laboratory for the examination of water in connection with the Hamburg works is one the best equipped which I have ever seen. It is placed in a separate two story brick building, which contains rooms for the various departments, and every facility for conducting the large number of tests which the rules require.

Berlin also draws its water supply from rivers and filters it. The populations upon the Havel and Spree are less than those upon the Elbe, but the watersheds are less, so that the pollution in proportion to the volume of water is not inconsiderable.

The filtration at Berlin is effected by some thirty acres of filters, which have been vaulted over as a protection from winter weather. Formerly open filters were used, and much difficulty was experienced from ice, and in 1889, during an unusually cold period, the filters became so far unserviceable, and the water supply deteriorated to such an extent, that the city suffered from a considerable epidemic of typhoid fever. Since that time the use of open filters has been abandoned as fast as new covered filters could be substituted.

Among the 30 cities in Germany which either have more than 100,000 inhabitants, or supply water to that number of people, there are 11 which supply filtered water, the raw water being in almost every case drawn from rivers. The other 19 cities are all supplied with ground water, but the aggregate population so supplied is somewhat less than the population in the 11

cities supplied with filtered water. The supply of ground water, in the volumes required by large cities has received a great deal of attention in Germany.

Dresden, with 300,000 inhabitants, is supplied from a filter gallery along the Elbe 4,900 feet long and 26 inches in diameter about 70 feet from the river, and 10 feet or so below low water. The walls of this gallery are built with perforations and are surrounded with coarse gravel and the natural material of the river bank. This gallery has been in use since 1875, and has always given an abundant supply of entirely satisfactory water. The level of the water in the gallery is only reduced by pumping to about five feet below the river, and at the time of my visit there were nearly 12 feet of water in the pump well. These works were built by Herr Salbach, and it is his idea that the six or eight million gallons of water drawn come entirely from the land side, and and that only insignificant quanties, if any, of the river water find their way to the pumps. It is his idea that there is an extensive bed of gravel all along the river for miles reaching up into Bohemia, and that in this gravel there is another river flowing beside the Elbe with lower velocity, but vastly larger cross-section, and that it is the water of this underground river which he obtains. It is for this reason that the projected extension of the Dresden works is placed on the other side of the river, and some miles away, to tap another portion of this subterranean river, as he feared that any extension in the present location would tend to unduly lower the ground water level, and to cause infiltration of water from the river.

Some miles above Dresden the Elbe comes through the so-called Saxon Switzerland between rock walls, and, so far as one can judge, over a rock bed. It was my first thought that these rocks would act as an obstruction to Salbach's underground river, and that the river, if such existed, must have its origin below this point, but Mr. Salbach informs me that the stone at this point is mainly porous sandstone, and is capable of allowing the passage of water, and in addition there may be fissures. It seems to me, however, that similar objections might be rightly raised to the theory that similar underground rivers are flowing parallel to many New England streams.

The newer ground water supplies have substituted separate wells with suction tubes for the galleries as it is said their construction for a given result is much cheaper. Leipzig, with 360,000 inhabitants, is supplied by such a series of wells located some 13 miles from the city. The water is taken from gravel beds which are probably an old course of the Mulde which still carry large volumes of water having their origin in that river, and so far as they are not diverted for water supply, reverting to it lower down. This is a particularly interesting scase the surface water from this neighborhood, so far as there is any, does not go into the Mulde at all, but in the other direction into the Saale. At this point the Mulde makes a little detour, and the Saale watershed goes almost to its banks, and the old Mulde channel thus lies to a considerable distance in the present Saale watershed. The country all about as far as the eye can reach appears to be perfectly flat except in a few places where ledges crop out. The surface shows a slope of about one in a thousand. The watershed of the little brook passing the works is quite insignificant and bears no

relation to the supply, and there is no large body of water above the surface for miles. This old river-bed is about three miles wide, and the gravel in it is from 50 to 70 feet deep. The wells constructed by the city reach in a straight line nearly across the entire width of this gravel. The first wells, 140 in number, covered about one-third the distance; afterward an extension of 90 wells was put down 33 feet apart, and the latest addition which I saw in the course of construction consists of 94 wells 60 feet apart.

The method of digging these wells is to put a 12-inch cast iron pipe down to the depth required, digging out the sand from the center as the pipe sinks; afterwards the permanent 7-inch pipe with a strainer about 16 feet long is introduced, and inside of that an independent copper suction pipe reaching nearly to the bottom. In addition a $\frac{3}{4}$-inch pipe is provided for taking samples and ascertaining the water level. When all is in position the 12-inch pipe first put down is drawn up, water is now pumped from the well by an electric pump operated from a trolley running the length of the extension. With rapid pumping much sand is at first drawn until the particles which cannot pass the rather coarse sieve form a gravel layer around that point and hold back the sand without further trouble. The ground water level is lowered by rapid pumping on four wells at a time by means of the electric pumps far enough below the surface to allow the permanent collecting pipes to be placed.

For this collecting pipe rubber connections are every where used instead of lead; they are said to be cheaper and tighter, and can be taken apart at any time without the slightest damage to the pipe, and they are also flexible. On a 2-foot pipe a rubber ring like a bicycle tire, but solid, and one-half as large again as the opening between the bell and spigot, but the exact diameter of the pipe, is placed on the end of the spigot and rolled into the bell enclosing and flattening the rubber ring. The joint so made is air tight for vacuum, and will hold at least four atmospheres of pressure without leaking. The joint is made complete in two minutes, under water if necessary, and, so far as known, it does not deteriorate with time. It can be taken apart and re-adjusted as often as desired. On the regular distributing pipes in a city, lead joints are ordinarily used, but I was told that on some bridges where flexibility was desired rubber had been used with satisfactory results.

The collecting pipe from these wells discharges into the pump well, which is lower than the point to which it is proposed to lower the ground water, and any air which may accumulate in the pipes is removed from time to time by an air pump connected with the highest points on the pipes. A siphon can be used in this way with lifts up to 26 feet. The water obtained in this way is of satisfactory quality in every way except that it contains a little iron. The first two series of wells were built so that each well could be separately tested for iron, and the worst wells were shut off. This arrangement has not, however, been entirely satisfactory, and this year no provision is made for shutting off single wells. It is found that in passing through the 13 miles of pipe and conduit (about half and half) to the distributing reservoir, and over the measuring weirs, the water becomes thoroughly aerated and the iron is precipitated. Filters have just been constructed through which this water will be passed in future at an extremely high rate, and is is believed that no further difficulty with iron will be experienced.

A record is kept of the height of water in the different wells, and also in other wells in the vicinity. Pumping for years from the first section has not lowered the water level in the other sections, in the least, and the flow of ground water, while slower below the wells, still continues in the same direction showing that even now the wells do not intercept all the water there. The entire capacity of the plant is now estimated at 16,000,000 gallons daily. The old works, without the last addition, have yielded up to 11,000,000 gallons.

Herr Thiem, consulting engineer for the Leipzig and other works, has an interesting method of estimating the capacity of a ground water supply. He sinks three wells equidistant from each other in the form of an equilaterial triangle. No water is pumped from them at first, but the water level is observed carefully for some days. From these observations he calculates the direction of the slope and consequently of the flow as follows: He calculates the point on a straight line, joining the wells having the highest and lowest water levels where the water level is the same as it is in the third well. Joining this point with the the third well gives a line at right angles to the line of flow. A fourth well is now sunk in exactly this direction, that is the line of flow, from one of the first wells, and the higher well is dosed with a quantity of salt solution, followed by enough water to force the salt into the surrounding gravel. Samples of water are now taken at intervals from the lower well and analyses show when the salt passes. From this is calculated the velocity of the ground water and in connection with the cross section of the gravel the quantity of water passing is estimated, and this is regarded as the capacity of the source, making allowance for variation of flow at different seasons. Herr Thiem has no confidence in pumping tests of wells short of years of continued use.

At Charlottenburg, which is one of Berlin's suburbs, a ground water is used which contains even more iron than that at Leipzig. In this case there is no flow through a conduit to oxidize the iron, and instead the water is taken through coke towers at a rate of 100,000,000 gallons per acre daily. The water in passing through the coke is everywhere in contact with air, and it is found that the water so treated can be filtered through an ordinary sand filter at a rate of 25,000,000 gallons per acre daily, yielding an effluent entirely free from iron. The capacity of this plant is 13,000,000 gallons daily. This process, which has been perfected by Herr Piefke, is also applied to a number of smaller supplies, and for removing the iron from the well waters used by a number of breweries in Berlin and in Breslau.

Munich has a ground water supply which is collected in still another way. The original supply was a series of springs along the side of a ravine in cultivated and wooded land which is rather elevated just where the foot-hills of the Alps commences. The soil on the country back, which undoubtedly furnishes the water, is mostly gravel and pervious, with more or less clay in places, and a layer of clay and slate below. The comparative even of the land is cut by a ravine of the river 150 to 200 feet deep which goes some distance below the intercepting layer of slate into the gravel below. Along one side of this valley above the clay were natural springs which were first taken

for Munich's supply, but it was found that the bulk of the water discharged through crevices in the slate below the surface into the river, and extensive galleries above the clay were built to intercept it. The bottoms of these galleries are concrete, with a stone arch over the top, five to six feet high, with a perforated tile pipe 18 to 24 inches deep below, communicating at intervals with the tunnel above. Under ordinary circumstances all of the water flows in the lower pipe, but when the flow exceeds its capacity it goes up into the upper channel. In a few cases the drain pipe was omitted altogether. The stone covering arch, except near the outlet, is laid without mortar, and is surrounded by gravel to allow the free admission of water. The whole is sunk in the clay to the depth of about three feet, but varying with the irregularities in the surface of the clay.

There are at present about 7,800 feet of these galleries in use of which 4,800 feet are walled without mortar, but the remaining 3,000 feet are also supposed to collect considerable water. These galleries must be 100 to 150 feet below the surface. The lowest yield from them was 15,000,000 gallons per day in March, 1887, and almost as low a figure was obtained in October, 1893, both times for a few days only. The springs have yielded at wet times up to 32,000,000 gallons for short periods, and the average quantity used by the city is about 12,000,000 gallons. The flow of the springs is always free, and as much of the water is sent to the city as is required, the rest being wasted into the river. The capacity of the aqueduct is 23,000,000 gallons. The length of the conduit to the reservoir is 19 miles with an average grade of 1 in 880, the conduit being for the most part $4\frac{1}{2}$ x $2\frac{1}{2}$ feet in size. It is seven miles from the distributing reservoir to the town, so that the entire distance is about 26 miles. The cost of the works was $2,100,000.

Among the world's great capitals Vienna has a unique supply. Its source is in the high mountains near the line of the Semmering railroad about 60 miles from the city. The mountains are of dolamite, with streaks of pure lime stone, all of tertiary origin. Under the whole is a continuous impervious layer of slate, just above which the springs are located. The bulk of the stone is solid, but there are many fissures through which the water flows. The surface of the stone has become disintegrated in places, and where the slopes are not too steep it is covered with trees. Otherwise there are bold rock cliffs which give a most romantic aspect to the valley. The material is apparently rather pervious, for excepting the place where the water flows from the springs there is little evidence of erosion upon the mountains, although the rain fall is rather heavy, averaging about 59 inches both on the summits and in the valleys. The tops of the mountains are nearly 7,000 feet high and have patches of perpetual snow, which, although they appear quite small from below on a hot summer day, are large enough by melting to swell the volume of the springs at the base of the mountains to from two to four times their winter flow.

The springs apparently have a tolerably direct communication with the surface in places, for a heavy rainfall will increase their flow in from six hours to two days, but the water never presents the slightest turbidity ; its temperature

is constant for the whole year at 41 to 44 degrees. The temperature of each single spring is entirely constant but all the springs are not exactly the same. As the mountains are uninhabitated, there is no reason to fear the presence of incompletely filtered rain water. Ordinary rains do not affect the flows. The Kaiserbrunnen, as the largest of the springs is called, was brought to Vienna in 1873 through an aqueduct 55 miles long, and having a capacity of 40,000,000 gallons. This spring furnished an abundant water supply during the warm months of the year, but was inadequate to meet the growing demand in the winter months when all the precipitation upon the mountains was in the solid form and there were no thaws to increase the flow of the springs. To aid the supply, a series of wells were put down ten years ago, near the line of the aqueduct, in the valley of a river which it was thought would add a considerable quantity of water in winter at a time when it was most needed. The supply from this source, however, has been rather disappointing not exceeding 3,000,000 gallons daily. In the last year other more distant springs have been connected, at an expense of $1,000,000 not including water damages.

The supply, at the time of my visit, July, 1894, 21,000,000 gallons, was drawn mainly from the Kaiserbrunnen with another spring near by, while the water from the higher springs, at least 46,000,000 gallons daily, was all going to waste. The new springs will be required in the winter only when the Kaiserbrunnen is low. The minimum winter yield of the present springs is about 19,000,000 gallons. The population of Vienna is 1,500,000; about one-half million, however, are in the recently annexed suburbs, and are not as yet supplied with Vienna water. It is desired to so supply them as soon as enough water in winter can be obtained.

Two projects are under consideration; one being investigated by Herr Salbach is for a series of wells in the valley of the Danube in the immediate neighborhood of the city, while Herr Kinzer, who has constructed the recent addiions to the present works, is working upon another spring water project of the same general nature but toward the Alps, about 150 miles away and among even higher mountains. He thinks that the cost of an additional supply of 40,000,000 gallons daily will probably reach $20,000,000. Further supplies could be got from the neighborhood of the present works, but the mill damages are too heavy, and in addition it would be necessary to construct a new conduit. I was told that the city paid $1,600,000 for mill damages alone, on the last addition to their supply of 10,000,000 gallons. The new project is upon government lands and there are no mill privileges. The aqueduct from the Kaizerbrunnen to Vienna has an average grade of over 10 feet in a mile, and the section above the Kaizerbrunnen for the recent additions has a fall of 1100 feet in 10 miles. The upper part of this is constructed of iron, and the arrangements are very different from the conduit built by Mr. Herschel for the East Jersey Water Company, a few years ago. The distance is cut up into sections, each having a fall of about 100 feet. At the end of each of these sections is a gate house, and the flow of water through the section is throttled by a gate at the lower end of the pipe which is regulated in such a way as to keep the pipe always full of water. This necessitates the use of much heaver pipe, as well as the construction and care of numerous gate

houses which are entirely avoided by Mr. Herschel's design. I was told that it was feared that if the water was allowed to flow down freely, the upper part of the pipe would be occupied by air, and that the pipe would become corroded and weakened.

Some miles of the conduit lower down were cut out of the solid rock, and as one rides up the excellent road, which was itself built as an adjunct to the conduit, the only signs of the conduit are the frequent holes in the limestone crags, through which the rock removed was brought out and dumped into the valley below. And the sizes of these dumps afford the best indication of the magnitude of the enterprise.

Paris has long been supplied with water for domestic purposes from springs in several valleys at a great distance from the city. The supply which was available from these sources up to about two years ago did not exceed 37,000,000 gallons daily, a quantity which was found inadequate for the two and a half millions of people dependent upon it. The city has an additional supply of water taken unfiltered from the Seine and from a canal, which was used for street washing, for manufacturing and other purposes, but was not ordinarily allowed to be used in the houses. Paris washes its streets instead of sweeping them, and the quantity of water employed is very large, exceeding 80,000,000 gallons for other than domestic purposes. When the quantity of spring water was inadequate to meet domestic requirements, the city for years turned on to the different wards of the city in regular rotation, river water. Before this was done the inhabitants of the wards were warned of what was coming, and were advised to refrain from using the water for drinking.

This condition of affairs was ended in 1892 with the completion of a new aqueduct from springs in the valley of the Arve, supplying a maximum of 32,000,000 gallons. The circular aqueduct for twelve miles has a diameter of five and one feet, and a fall of one in 2500; for 46 miles it has a diameter of six feet and a fall of one in 3,300; and in addition there are five miles of siphons where two lines of 40 inch pipe are used having a fall of one in 800. The total length of this aqueduct is 63 miles and the total fall is 132 feet. The walls are 8 inches thick, of the natural stone of the country laid in Portland cement. The city is allowed by law to take a quantity of water, not exceeding 30,000,000 gallons, and to prevent more than this from being used an ingenious device at the head of the aqueduct is employed. The water flows through a submerged orifice at a determined distance below a very long overflow weir, and as soon as the quantity of water reaches the legal limit the excess commences to flow over the weir and back into the river. Below this point there is another spring connecting with the aqueduct which yields an additional 2,000,000 gallons.

The springs supplying the water are scattered in the valley for about 2 miles above the head of the aqueduct, and are connected with three and one half miles of conduit. They are only a short distance below the surface. The springs, ten in number, were natural springs which formerly discharged over the surface into the river. They have been enlarged, cleaned

and deepened and covered in ; the bottoms are coarse pieces of flint. The houses covering them are 15 to 40 feet in diameter. There are no other springs in the valley. The river is dry since the spring water was collected and poplar trees were dying for the lack of water. The surrounding country through which the water probably comes, is rolling and somewhat clayey with much flint mixed with the clay. The rock is chalk also mixed with flint, and in the valley of the river there is gravel mixed with fragments of flint, all of which is rather porous. The springs are in this gravel but I could not ascertain its extent. Judging from the contour lines the springs drain the country for 15 miles back. It is all cultivated land, and has an ordinary farming population. There is no manufacturing. The maximum flow of the springs is about 50 per cent above the minimum which comes in September. Nearly all of the water comes into the ten springs themselves, but in two or three places the collecting mains going over the minor springs are arranged to allow the entrance of water ; otherwise the mains are water-tight, and the water in the drains built below them, to aid in construction, is discharged into the river. The aqueduct and the work at the springs cost in all $4,000,000. The damage suits for water power and loss of water for irrigation are still pending, but I was told that it was expected that they would be settled for about $3,000,000, making a total cost of $7,000,000. $100,000 was paid for the springs themselves, and the surrounding land.

The present minimum of spring water at Paris, from all the existing sources is about 53,000,000 gallons. This is the only water taken into private houses. Only a fraction of the houses have water-closets, but the practice is increasing and more water will be required. The present sources are incapable of further devolpment. For the future, there are two projects, one for a grand system of filtration of river water; the other for a supply of spring water from the mountains in Haute Marne, 180 miles east of Paris. Studies are about to be commenced for these supplies, the intention being to secure an average of 67,000,000 gallons daily.

The present supplies will prevent the necessity of using unfiltered river water for, at least, ten years. The suburbs of Paris are all supplied by a private company which is just building an extensive filter plant which it is proposed to use in connection with the Anderson Revoling Purifier Process taking the rain water from the Seine above Paris.

Some of the Dutch cities have a particularly interesting system of collecting their water. A large part of Holland consists of land as low or lower than the ocean, and the highest land in the country is a row of dunes, only a few miles wide, extending along the coast from Amsterdam to the Hook of Holland. These dunes consist of fine sand, and the level of the ground is from ten to twenty feet above the ocean. It is entirely uninhabited. The water is collected from this area by a system of open canals. The water in the canals supports algae growths and becomes unsuitable for use in its raw state and must be filtered. At Amsterdam about 6,200 acres of dunes are drained by 15 miles of open canals below the ground water line. The yield of the land is equal to 14 inches of rainfall on the entire area out of the 28 inches total fall. The sum-

mer rainfall is believed to be all lost for water supply by evaporation, while the bulk of the winter precipitation is utilized. The water as it comes from the ground into the canals contains iron, but this is all removed by natural processes before the water reaches the filters. The average supply of water for the past year from these sources has been 6,500,000 gallons, with a maximum of 8,000,000 gallons.

Some years ago this supply became inadequate to meet the growing demands of the city, the water company built another plant on the other side of the city which takes its water from a canal or river which is not excessively polluted and is carefully filtered. These works, built at a cost of $3,000,000, were intended to supply 11,000,000 gallons, but the city authorities who wished to secure control of the water-works decided that this water did not meet with the sanitary requirements, and that it could not be used for domestic purposes. It is, therefore, at the present time, only used for street sprinkling and other public and manufacturing purposes, about 4,000,000 to 5,000,000 gallons being required. The city insists that the company must provide an additional supply of dune water, the estimated cost of which will be two and a half million dollars, and at the same time will not authorize the company to increase their capital stock. The object is evidently to put the company in an unfavorable a position as possible in order to allow the city to aquire it on favorable terms. The supply of Leyden and of the Hague are of the same general nature as the dune supply of Amsterdam.

It has been suggested that if covered collectors were used instead of open canals for collecting the water, the filtration could omitted and an equally good water supplied. On the other hand it is said that covered collectors in the extremely fine sand which there exists, become rapidly choked and require to be dug up from time to time at great expense. And further that the water if so collected would contain iron, and would require treatment which might be as expensive as the present filtration. For the filtration of this dune water the dune sand itself is used, which is much finer than is elsewhere used for filtration, and is here possible on account of the comparative purity of the raw water.

Brussels with its two hundred thousand inhabitants is supplied by ground water drawn from some five miles of collecting conduits in fine sand underneath a forest which also serves as a city park. The drains are generally from 100 to 150 feet below the surface. The possibilities of the supply from this area are apparently nearly reached. Brussels is desirous of annexing her suburbs and forming a greater Brussels with a population of about half a million, and in case this is done an additional water supply must be procured. The city engineers are talking of an extension along the present lines but in newareas, and there is also a project for a filtered river water supply.

The Continental cities are almost invariably supplied with either ground water or filtered river water. The use of impounding reservoirs is practically unknown. Chemnitz and Konigsberg have small reservoirs as auxiliaries to other means of supply, but it is only in England that we find great dams retaining large volumes of water similar to those so commonly used in

America. Liverpool already derives its water supply from such a source in the Welsh mountains, and Manchester, Bradford and other towns have similar supplies in the north.

Birmingham is just commencing the construction of an aqueduct to Wales, 60 miles away, at an enormous expense, and there has been talk of a similar supply for London, but in the latter case a royal commission appointed to consider the subject has decided that the present sources can be utilized for many years to come without bad results and at a less expense.

The waters from impounding reservoirs in England, although the water sheds are entirely free from pollution, are generally filtered. In this way all trouble from bad tastes and odors due to algae growths, as well as from temporary turbidities in times of storms, are avoided, and the results are believed to be commensurate with the cost of filtering the water. There are, however, a number of towns, including Manchester, which supply such water without filtration, and Glasgow draws its water from Lock Kathrine without filtration. In Germany reservoir water is required by law to be filtered whether it is subject to pollution or not.

The following table contains a list of some of the principal European cities with their populations, the quantities of water supplied daily in millions of American gallons and the sources of the water. I have simply included some data which I happen to have with no attempt at completeness. Most of the statistics are for 1892 or 1893, but those of St. Petersburg and Warsaw are for 1890, and for the English cities, except London, the figures are taken from a local government report for 1887. Most of the figures are calculated from pumping records for an entire year; the statistics for the gravity supplies at Paris and Vienna may be less exact. The Munich and Frankfort supplies are also gravity but the figures given are calculated from comprehensive weir measurements.

FILTERED RIVER WATER SUPPLIES.

CITY.	Population Supplied.	Million Gallons Daily.	Gallons per Head Daily	From Rivers.
London*	5,030,000	190	38	Thames and Lea.
Berlin	1,606,000	26	16	Havel and Spree.
St. Petersburg	960,000	39	40	Neva.
Hamburg	583,000	32	53	Elbe.
Warsaw	500,000	6	12	Weichsel.
Breslau	335,000	7	22	Oder.
Rotterdam	240,000	13	54	Maase (Rhine).
Magdeburg	200,000	5	24	Elbe.

*Exclusive of ground water supply.

FILTERED WATER FROM OTHER SOURCES THAN RIVERS.

CITY.	Population Supplied.	Million Gallons Daily.	Gallons per Head Daily.	Source.
Amsterdam	515,000	10	20	Dune and canal.
Liverpool	815,000	22	27	Storage reservoir.
Bradford	364,000	12	33	" "
Dublin	327,000	18	55	" "
Birmingham	600,000	—	—	" "

GROUND WATER SUPPLIES.

CITY.	Population Supplied.	Million Gallons Daily.	Gallons per Head Daily.	Source.
Paris*	2,500,000	53	21	Springs.
Vienna	1,000,000	23	23	Springs.
Buda Pesth	500,000	22	44	Wells by Danube.
London (Kent Co.)	460,000	16	35	Wells in chalk.
Leipzig	360,000	5.5	15	Wells.
Munich	300,000	11.5	38	Springs.
Dresden	280,000	6.0	21	Filter gallery by Elbe
Cologne	255,000	11.5	45	Wells by Rhine.
Frankfort-on-Main	186,000	6.7	36	Wells and springs.

*In addition 80,000,000 gallons of river water are used for public and manufacturing purposes.

UNFILTERED SURFACE WATER SUPPLIES.

CITY.	Population Supplied.	Million Gallons Daily.	Gallons per Head Daily.	Source,
Manchester	963,000	24	25	Storage reservoir.
Sheffield	324,000	—	—	" "
Glasgow	794,000	50	64	Loch Katrine.

SIX LARGEST AMERICAN WATER SUPPLIES FOR COMPARISON.

(Am. W. W. Manual, 1890.)

CITY.	Population Supplied.	Million Gallons Daily.	Gallons per Head Daily.	Source.
Chicago	1,099,850	152	140	Lake Michigan.
Philadelphia	1,046,964	138	132	Rivers.
New York	1,515,301	121	79	Storage reservoir.
Brooklyn	776,838	55	72	Wells and reservoirs.
Buffalo	255,664	47	186	River.
Boston	527,606	42	80	Storage reservoir.

DISCUSSION.

MR. CLEMENS HERSCHEL. Mr Chairman and gentlemen, it is only because I like to do my share of any work my fellow-members may be engaged in, that I consent to say anything at all. There is a new kind of entertainment abroad now, called a picture play, and I saw one the other night. (Laughter.) Oh, I am not talking about "living pictures," but of a "picture play," as it is called. The room is darkened, and a gentlemen stands in one corner where he has a little light, and reads a story or a play, and while he is reading, stereopticon pictures are thrown on the screen to illustrate the various phases of what he is reading. And similarly as my friend Mr. Hazen was giving us his account of his European trip and his description of the various water works he visited, I could shut my eyes and see pictures passing before the vision of my mind to the rhythm of his voice, because I have had the pleasure of having been in most of the places he described. It is exceedingly instructive to observe how the world changes and progresses all together. We sometimes, seeing only the progress in our own immediate vincinity, forget that all the rest of the world is also traveling and working and progressing. But we find that the same problems that confront us here are also to be struggled with in Europe. The cities there are growing very fast, growing to an extent that few of us think is possible. I have seen some statistics of the larger cities in Europe which would lead one to believe, looking at the statistics alone, that he was reading about Chicago, or any other typical western city.

These problems of water supply that are being met with over there are, I imagine, the forerunners of those that we have got to encounter here; and that too in a very short time indeed. The population in the vincinity of Boston, for example, is almost as dense, in fact it is as dense, as that of many places that Mr. Hazen has mentioned, and although his notes were taken so far away from us, I believe they are exactly applicable to our own situation. All we have got to do is to look ahead a very little while, and we will see the same problems confronting us that have been met, and overcome, in Europe. I have been very much interested in Mr. Hazen's paper, and am glad to have been here to hear it.

MR. BRACKETT. If Mr. Herschel, who has visited these places described by Mr. Hazen, can appreciate the paper, I am certain that those of us who have not had the pleasure of seeing them, can appreciate still more what we have heard. I have been very much interested in all the details of the paper, and it seems to me that many points have been brought out which we could profitably discuss. For example, there is the question of the consumption of water in European cities as compared with American practice. It appears from the figures presented that there is a large difference in the consumption of European as well as American cities, the figures quoted varying from 12 to 65 gallons *per capita*. The larger of these quantities would be considered very reasonable for any of the large cities of the United States.

In considering the quantity of water required in any city, a careful study should be made of the conditions which obtain in that particular place. The

demands for manufacturing and trade vary to a great extent in different communities. Some branches of manufacturing require large quantities of water while others need little or none. One manufacturing city may be so situated that all of the water must be furnished by the public supply, while in another case the different factories can obtain their supplies from rivers or wells. New Bedford and Fall River are both manufacturing cities; in New Bedford the mills obtain a supply from the public water supply and the use for manufacturing purposes is equivalent to about 20 gallons per inhabitant, while in Fall River the mills obtain their supply from a river running through the city and the manufacturing use is only two gallons per inhabitant. In Boston the use for manufacturing and trade purposes is about 30 gallons per inhabitant an amount larger than the total consumption of many of the European cities quoted by Mr. Hazen.

Furthermore there is a great difference in the practice of different communities in regard to the general use of water closets, baths, wash trays and other modern plumbing conveniences. Meter measurements, made by Mr. Whitney in Newton, showed that 619 families not using water closets or baths required but 6.6 gallons per person while houses supplied with modern plumbing conveniences required 26.5 gallons for each person. In London, Eng., it was found that 8,183 persons in houses having water closets and baths, used 25.5 gallons per person showing that the quantity required in London or in Newton is the same under the same conditions.

The general use of water fixtures is increasing in this country and this increases not only the use but also the waste of water. The number of water fixtures *per capita* in Boston has nearly doubled during the last 20 years.

Another fact which has a very important bearing on this question is that the prevention of waste has received much more attention in Europe than in the United States. When the cities of the United States are obliged to bring their supplies from sources 60 miles distant, or to filter their water as is now required in Germany, more attention will be given to the subject of waste prevention and the quantities used per inhabitant will approach more nearly to European practice.

MR. F. L. FULLER. I would like to ask Mr. Hazen to tell us a little about means for fire protection in these European cities.

MR. HAZEN. All the buildings are fireproof, and there are no fires of any consequence. The only chances for considerable fires are furnished by warehouses filled with combustable materials. I have seen a so-called fire in Berlin and they simply let it burn out in the room in which it started, not putting on too much water, for fear of damaging the adjoining rooms, and the people above and below lived on without being very much disturbed. I have heard about the fire department coming out in Berlin, I didn't see this myself and cannot vouch for it, but an American friend told me that when the fire alarm was rung a man was sent out to wake up the firemen, and when the firemen gathered finally, the roll was called, and then the chief told the men to harness up the horses, and when they got to the fire the roll was called again.

MR. NOYES. Mr. President, Mr. Kieran, of Fall River, has suggested to me

that it would be of interest, and furnish information of considerable importance, if the various superintendents brought in at the next meeting a statement in regard to the consumption of water for each month of the year 1894, giving the total consumption, the consumption *per capita*, and if possible, give the amount of water used for domestic and the amount used for manufacturing purposes.

A comparison of the amount of water *per capita*, used in the various municipalities is exceedingly interesting, Mr. Brackett has been giving it a very exhaustive study, and I hope before long the association will have the benefits of studies recently made by Mr. Brackett, as to the requirements for a proper water supply. Having had an opportunity to see some of the conclusions reached by these studies, and having been obliged to make studies myself with reference to the consumption of water in different places, I find a great many surprising facts, which it is difficult to account for, such as to the excessive amount of water used in some places, and the small amount used in others. Take New Bedford, a manufacturing city, where many of the large cotton mills are located near the salt water, about as much water is used there for manufacturing purposes as the city of Fall River, also a manufacturing city, uses for its whole supply. There are many peculiar conditions found in the metropolitan districts of Boston, and many cases when one thinks that he can trace the cause by analogy, but suddenly finds some unusual condition which leads one to doubt the correctness of his conclusions. Mr. Kieran suggests that about 90 per cent. of the water in Fall River is metered ; but in Newton, where the consumption is something like 60 gallons *per capita*, the water also is very largely metered. I might say, however, that there is a single manufacturing concern which uses at the rate of 10 or 12 gallons *per capita*.

Mr. Brackett. If the members would follow out the suggestions of our association in presenting their annual reports, they would accomplish not only the result which Mr. Noyes suggests, but a great many other interesting facts could be obtained and presented in tabular form in the Journal. In response to our request, 23 cities and towns adopted this form of report in 1893, and we hope the number will be doubled next year, and that before many years we shall have uniform reports from the whole country. I think the gain outside of New England has been greater in proportion to our membership than it has in New England, which does not speak very well for our resident members.

PORTABLE PLATFORM TO AID IN EXCAVATING TRENCHES.

BY

R. C. P. COGGESHALL, Superintendant, New Bedford, Mass.

[Read June 14th, 1894].

Last year the Water Department of the City of New Bedford had occasion to remove over 1½ miles of wrought iron cement-lined main pipe replacing the same with cast-iron pipe.

The location of this work was through the principal thoroughfares of New Bedford which are not generally more than forty feet in width.

In our usual operations it is customary to throw the earth on the sidewalk side of the trench, and the inside slope often interferes with the ordinary use of the sidewalk.

As the streets upon which this work was done were largely occupied with stores, I was instructed by the Water Board to take steps to keep the passage in front of the stores clear as possible during the progress of the work.

The device which was used was worked out by Franklin M. Ashley, now deceased, then foreman of the distributing system.

It consists of two platforms 4′x12′ hinged together, and when in use, one is horizontal upon the ground, the other vertical and held in position by braces removably attached to the first named. When not in use the two platforms fold together and are easily handled.

The material used in making the platforms was 3″x 4″ spruce joist and ⅞″ spruce boards.

It proved to be an admirable device for the use for which it was intended, and the department received much praise from the general public, as well as the storekeepers.

But other features were soon observed. Its use dispensed with the necessity of keeping men employed in trimming the inside dirt slope and in endeavoring to maintain an apology for a passage way.

As the dirt is left sloped one way only, the labor of back-filling is largely reduced.

The sidewalk and street are left clear upon the removal of the platform.

The most surprising result was, that a large saving in labor was effected by its use. Mr. Ashley estimated this to be at least 25 per cent. Subsequent experiments prove that his estimate was probably not far from correct.

A careful experiment has lately been conducted by the writer in a common road where there is neither paving nor macadamizing. The size of pipe laid was 8 inch, depth of trench being 4 feet 10 inches. 300 feet were first laid without the platform, and on the next 300 feet the platform was used.

Similar conditions existed in both cases. The exact cost of simply excavating and backfilling in both cases was as follows: [This of course does not include the placing of the pipe.]

Without platform ..... $19\frac{3}{10}$ cents per foot.
With use of platform including labor of handling same and carting ..... $14\frac{7}{10}$ cents per foot.

This shows a saving of 24 per cent in favor of the use of the platform.

If the cost of carting the platform could be extended over a longer line, say 1,000 feet or upwards, the saving in favor of the platform would approach 30 per cent.

The attention of the members of the Association is hereby called to this device as I think it will be found to possess unusual merit.

DISCUSSION.

MR. FULLER. I should think that if the plan suggested by Mr. Coggeshall was adopted there would be more tendency to cave in the trench, as the weight would be more concentrated and nearer the trench than if sloped off the other way. In some localities, of course, that might not be a matter of much importance, but it might be in some other locality.

MR. COGGESHALL. There has been no tendency in our experience for the trench to cave. Possibly it might do so if the trench was deep, but for an ordinary water pipe trench, I would not expect any trouble from this source.

STATISTICS

FOR

THE YEAR 1893.

IN FORM ADOPTED BY THE

New England Water Works

ASSOCIATION.

TABLE I—GENERAL AND PUMPING.

TABLE II—FINANCIAL.

TABLE III—CONSUMPTION.

TABLE IV—DISTRIBUTION—MAIN PIPE.

TABLE V—DISTRIBUTION—SERVICE PIPE.

Compiled by the
SENIOR EDITOR,
Boston, Mass.

TABLE I.—GENERAL AND PUMPING.

Number.	Name of City or Town.	Date of Construction	By whom owned.	Source of Supply.	Mode of Supply.	1. Builders of Pumping Machinery.	2. Coal Used.	Per cent ashes.	Price per ton of 2,240 lbs.
1	Bay C'y, Mich.	1872	City	Saginaw Bay	Direct Pumping	Holly Mf'g Co.	Bituminous & Pine Slabs		$
2	Boston, Mass.. (Cochituate)	1848	"	Lake Cochituate and Sudbury River.	Gravity & P to Res.	Holly Mf'g Co.	Bituminous	7.6	4.75, 5.00, 5.30
3	Boston (M'ttic)	1864	"	Mystic Lake	Pump to Reservoir	H. R. Worthington	"	10.5	4.12 to 4.45
4	Brockton, Mass	1880	"	Storage Reservoir	Pump to S. P.	H. R. Worthington	"	9.7	5 28
5	Burlington, Vt.	1867	"	Lake Champlain	Pump to Reservoir	H . Worthington	Anthracite and Mill Shavings		5.20 & $36 per wk. for 23 wks.
6	Fall Ri'r, Mass	1874	"	Watuppa Lake	Pump to S. P.	H. R. Worthington & Davidson S. P. Co.	Bituminous	7.5	
8	Lynn, Mass...	1870	"	Storage Reservoir and Saugus River.	Pump to Reservoir	I. P. Morris and Loretz.	"		5.04
9	N. B'df'd, Mass	1866	"	Acushnet River	Pump to Reservoir	Quintard I. W. and H. R. Worthington.	Bituminous & Anthracite	8.0 16.0	4.00 3.45
10	N. London, Ct.	1872	"	Lake Konomoc	Gravity				
11	Newton, Mass.	1876	"	Filter basin and driven wells.	Pump to Reservoir	G. F. Blake and H. R. Worthington.	Bituminous	6.0	4.90
12	Oberlin, Ohio.	1887	"	Vermillion River	Pumping	Deane S. P. Co.	"		1.55, 2.20
13	P'ym'th, Mass.	1885	Town	Ponds	Gravity and Pump	H. R. Worthington	"		4.80
14	Quincy, Mass.	1883	City	Storage Res. and wells	Pump to S. P.	Deane S. P. Co.	"	9.4	4.60
15	Reading, Pa...	1890	Town	Filter gallery	Pump to S. P.	Blake Mf'g Co.	"		5.25, 4.42
16	Spring'd, Mass	1864	City	Storage Reservoir	Gravity				
17	Taunton, Mass	1876	"		Pump Direct	Holly Mf'g Co.	"	13.0	4.24
18	Toronto, Can..	1872	"	Lake Ontario.	Pumping.	H. R. Worthington. Inglis & Hunter. G. F. Blake Man. Co	Anthracite		4.19
19	Troy, N. Y....	1833	"	Hudson River and Storage Reservoir.	Gravity and Pump to Reservoir	Holly Mf'gCo.	Bituminous & Anthracite	18.0	3.30, 2.34
20	Waltham, Mass	1872	"	Filter Basin	Pump to Reservoir	H. R. Worthington	Cumberland	14.0	
21	Wellesl'y, Mass	1884	Town	Two Wells	Pump to Reservoir	G. F. Blake and H. R. Worthington.	Cumberland & Screenings	9.1	5.10, 2.67
22	Woon'k't, R. I.	1884	City	Crooks Falls Brook	Pump to Tank	H. R. Worthington and Deane S. P. Co.	Bituminous	7.0	4.38
23	Yonkers, N. Y.	1874	"	Storage Reservoir on Grassy Sprain Brook.	Pump to Reservoir and Stand Pipe	Wm. Wright and H. R. Worthington.	Anthracite	15.0	5.09

TABLE I.—GENERAL AND PUMPING.—CONTINUED.

Number.	3. Coal consumed for the year, lbs.	4. Lbs. of wood / 3.	5. Total fuel consumed for year, lbs.	6. Total pumpage for the year in gallons.	7. Av'age static head against pumps.	8. Av'age dynamic h'd ag'st pumps.	9. No. of gals. pumped per lb. of coal.	10. Duty in ft. lbs., per 100 lbs. of coal, no ded'ct'ns.	11. Cost per mil. gals. pump'd into res. Fig. on pumping station expenses.	12. Cost per mil. gals., raised 1 ft. high. Fig. on pumping station expenses.	13. Cost per mil. gals. p'mped into res. Fig. on total mai'tenance.	14. Cost per mil. gals. raised 1 ft. high. Fig. on total mai'tenance.
1				1,044,256,236		113.24			$	$ 0.062	$ 39.77	$ 0.351
2	4,210,241		4,210,241	3,510,730,100		126.71	834.3	88,118,600	6.38	0.05		
3	9,188,000		9,188,000	4,074,479,200		149.36	443.5	55,239,700	8.40	0.056		
4	468,972	250	469,222	252,780,531		60.00	568.0	26,957,683	10.90	0.18	113.00	1.88
5				288,090,575	289.0	316 00			19.45	0.061	96.77	0.306
6	2,691,670		2,691,670	851,869,000		186 03	316.5		13.57		152.74	
8	958,817	433	959,250	752,691,940		161.5	784.6	105,659,538	6.94	0.043	82.50	0.513
	809,783	517	810,300	610.018,750		158.9	752.6	99,736,937				
9	1,171,950	103	1,172,053	754.523,052	125.9	135.2	644 0	72,588,530	6.87	0.0525	43.59	0.333
	264,204	333	264,537	128,138,992	125.3	126.5	485.0	56,074,821				
	1,174,473	400	1,174,873	927,737,876	125.6	127 9	790.0	84,237,392				
11	1,264,800	10,000	1,27 4,800	499,279,664	235.0	265.0	391 0	86,559,000	14.70	0.055	196.22	0.74
12	438,300		428,300	31,000,000	70.0	70 0	71.0	4,129,000	48 06	6 87	142.75	2.04
13	229,095		229,095	103,475,400	65.0	66.0	455.0	25,051,625	16.81	0.254	103.35	1.55
14	1,047,812	680	1,048,492	266,264,099	205.4	210.0	254.0	44,476,728	19.03	0.09	52.98	0.252
15	443,561		443,561	80,895,240	219.0	238.0	181.9	36,200,337	33.47	0.14	140.08	0.588
17			920,100	387,375,344		152.1	421.0	53,406,265	15 89	0.104	119.57	0.786
18	26,013,840	19,911	26,033,751	7,975,225,800	214.0	219.78	255 5	56,106,500	17.76	0 081	58.79	0.267
19	9,527,821		9,527,821	2,251,529,094	231.0	242.0	236.0	47,694,180	12.91	0.0563	34 95	
20	1,500,600			385,073,405	164.0	190.0	256 0	40,663,230	21.71	0.114	121.45	0.634
21	437,434	180	437,614	73,317,960	250.0	278.0	167.0	38,843,879	21.46	0.079	163.02	0.586
22	833,960	634	434,594	206,107,880	241.4	243.0	119 0	22,418,062	15.56	0 063	136.43	0.55
					244 9	249.6	218 0	48,546,900				
					258 8	240.0	264.0	53,020,760				
23	46,778	1,598	146,778	10.097,203	185.0	196 0	218.0	35,284,300	13.72	0.0624	109.70	0.499
	3,204,546		3,206,147	827,157,436	185 0	220.0	258.0	47,336,200				

TABLE II. — FINANCIAL.

Number.	Name of City or Town.	Receipts from Consumers.					Receipts from Public Funds.				
		A.	B.	C.	D.	E.	F.	G.	H.	I.	J.
		Rates, Domestic.	Rates, Manufacturing.	Net Receipts for Water.	Miscellaneous Receipts.	Total Receipts.	Hydrants	Fountains	Street Watering.	Public Buildings.	General Appropriation or Miscellaneous.
1	Bay City ...	$ 17,615.69	$ 5,780.10	$ 23,395.79	$ 431.75	$ 23,827.54	$	$	$	$	$ 28,910.00
2	Boston, Coch.			1,637,531.94							
3	" Mystic			421,574.18							
4	Brockton			36,242.39	109.81	36,352.20	3,000.00				
5	Burlington, ...	34,400.00	4,430.37	38,830.37	899.75	39,730.12	1,200.00	325.00		75.00	
6	Fall River ...			119,046.09	8,251.90	127,297.99					13,500.00
7	Fitchburg	41,597.17	12,906.33	54,503.50		54,503.50					
8	Lynn	134,321.61	40,616.97	174,937.58	2,131.48	177,129.06					20,000.00
9	New Bedford	72,681.88	8,195.73	80,877.61	199.55	81,107.16					59,200.00
10	New London .			35,711.01							4,000.00
11	Newton	65,650.75	4,627.18	70,277.93	4,600.57	74,878.50	13,520.00	1,238.54	2,250.00	1,095.27	326.42
12	Oberlin	2,276.17	328.25	2,604.42		2,604.42					2,375.00
13	Plymouth	15,827.97	1,326.00	17,153.97	676.51	17,830.48					
14	Quincy					32,260.41	3,900.00	200.00	300.00		
15	Reading	5,283.34			218.93	5,502.27					5,500.00
16	Springfield ...			160,936.78	22,404.91	183,341.69	13,820.00	1,680.00		3,678 50	
17	Taunton	36,479.11	9,997.97	46,477.08	81.87	46,558,95	3,500.00	1,502.32	800.00	550.24	
18	Toronto			361,395.82	16,184.86	377,580 68	55,600.00		25,000.00	3,599.18	1,139.00
19	Troy	68,817.88	17,286.26	86,104.14	7,623.32	93,727.46					
20	Waltham	46,578.28	5,259.99	51,838.27	10,059.37	61,897.64	3,017.50	280.00		745.50	
21	Wellesley.....	6,530.04	250.33	6,780.37	569.91	7,350.28	3,300.00	400.00	400 00	95.43	
22	Woonsocket ..	24,585.79	5,636.72	30,221.51	158.21	30,379.72	13,525.00	869.04	2,105.32	481.98	9,922.93
23	Yonkers	70,201.63	21,971.07	92,172.70	1,348.68	103,521.38	14,310.00				

TABLE II.—FINANCIAL.—CONTINUED.

Number.	K. Gross Receipts.	AA. Management and Repairs.	BB. Interest on Bonds.	Miscellaneous Expenses.	Total Maintenance.
1	$ 52,737.54	$ 12,610.06	$ 28,910.00	$	$ 41,520.06
2	1,693,358.44	433,408.18	826,077.88		
3	476,399.60	160,643.97	18,707.59		
4	39,352.20	6,911.66	22,685.83		29,597.49
5	40,330.12	18,794.88	9,075.00		
6	140,797.99	46 246 51	98,040.00		
7	54,503.50	23,111.15		20,639.76	43,756.91
8		38,707.17	74,028.50		112,735.67
9	140,277.16	31,122.84	37,200.00		68,322.84
10		7,945.41	22,140.00		30,085.41
11	93,308.73	15,475.32	82,500.00		
12	4,979.42	2,050.40	2,375.00		4,425.40
13	17,830.48	5,587.43	5,004.00		10,591.43
14	36,660 41	11,370.96			
15	11,002.27	4,532.31	6,800.00		
16	202,520.19	34 397.88	88,985.00		
17	52,911.51	15,254.40	31,063.00		46,317.40
18	462,918.80	182 210 78	188,965.00		
19	93,727.46	56,715.45	13,285 20		70,000.65
20	65,940.64	28,796.42	17,973.75		
21	11,545.71	4,152.83	7,800.00		11,952.83
22	57,284.99	10,086.55	18,033.29		28,119.84
23	117,831.38	30,892.45	60,950.00		91,842.45

TABLE III.—CONSUMPTION.

Number.	Name of City or Town.	1	2	3	5	6	Percentage of total consumption metered.	7	8	9	10
		Estimated Population.			Quantity used through domestic meters—gals.	Quantity used through manu'f'tring meters—gals.		Average daily consumption, gallons.	Gallons per day.		
		Total at date.	On line of pipe.	Supplied at date.					Each inhabitant.	Each consumer.	Each tap.
1	Bay City	33,000	19,500	13,500	48,419,877	61,676,139	10.5	2,860,976	86.6	212.0	1,596
2	Boston, Cochituate	441,400		435,000	4,252,830,000		24 5	47,453,200	107.4	109 1	713
3	" Mystic	127,300		126,000	701,372,910		17.9	10,742,500	84.4	85.3	480
4	Brockton	30,000	27,000	24,000	90,000,000		34.0	730,527	24.0	30.0	200
5	Burlington	15,000	14,600	14 300	43,213,568	14,404,522	20.0	789,289	53.0	55.0	303
6	Fall River	87,773		81,000				2,333,888	26.6	28.8	
7	Fitchburg	27,500	25,000	22,000	44,685,000	173,726,000	30.0	2,000 000	72.0	90.0	560
8	Lynn	69,653		66,850	213,400,000		15.6	3,743,758		56.0	
9	New Bedford	55,000	45,000	44,158	9,249,864	278,975,304	15.5	4,998,015	99.0	113.0	664
10	New London	14,500	14,300	13,100			30.0	1,141.565	78.7	87.1	463
11	Newton	28,300	27,800	27,300	187,000,000	27,000,000	42 8	1,369.684	48.4	50.2	259
12	Oberlin	4,500	3,500	1,800	1,683,000	900,000	8.4	85,000	19.0	47.0	260
14	Quincy	20,000	14,000	10,546	4,006,582	13.002,180	6 3	729,490	36.0	69.0	386
15	Reading	4,200	3,600	3,000	736,158	0		221,630	52.7	61.5	369
16	Springfield	50.526	43,000	37,000	271,193,619		17.2	4,320,000	86.0	117.0	617
17	Taunton	25,448	23,400	22,855	53,746,000	96,898,500	38 9	1,061,302	42.0	46.0	292
18	Toronto	188,904	185,000	185,000	612,827,025	88,471,188	10.6	18,127,158	115.1	117.6	545
19	Troy	65,000	60,000	58.000	355,088,652		11.6	8,364.463	128.0	144.0	1,293
20	Waltham	21,000	20,000	19,500	26,859,146			1,054,968	50.2	52.7	360
21	Wellesley	3,625	3,435	2,900	9,923,597	492,746		200,871	55.0	58.0	329
22	Woonsocket	25,000	23,000	20,000				559,508	22.4	25.4	361
23	Yonkers	35,000	31,000	30,500	263,000,000	274,000,000	64.0	2,294,000	66.0	75.0	700

TABLE IV.—DISTRIBUTION.—MAIN PIPES.

Number.	Name of City or Town.	1. Kind of pipe used.	2. Size of distribution pipe in inches.	3. Length extended during year, feet.	4. Length discontinued during year, feet	5. Total length in use, miles.	6. Cost of repairs per mile.	7. No. of leaks per mile.	8. Length of pipe less than 4 inches diameter, miles.	9. Hydrants. Number added.	10. Hydrants. Total in use.	11. Stop cocks Number added.	12. Stop cocks Total in use.	15. Range of pressure.
1	Bay City	Cast iron & Wyckoff pat.	3—20	7,348		42.5	$18.98	1.5	.66	14	366	19	630	35—38
2	Boston, Cochituate	Cast iron.	4—48	148,480	10,776	560.		0.6	2.1	189	6,042	296	6,206	
3	Boston, Mystic	Cast iron & cement lined	3—30	22,745		164.8		0.6	5.5	83	1,306	138	1,937	
4	Brockton	Cast iron & cement lined.	6—30	10,995		48.8	3.21	0 43		20	421	20	379	53—60
5	Burlington	C. l. i., w. i. & cast iron.	¾—16	3,898	3,283	31.56	9.00	0.5	4.	0	172	22	347	70 - 85
6	Fall River	Cast iron.	6—24							40	702	40	714	80
7	Fitchburg	Cement lined & cast iron.	2—30	16,736		55 35	14 00	0.4	1.96	29	359	18	403	
8	Lynn	Wrt. i., ct. l. & cast iron.	2—20	27,517	10,812	120.1				26	773	22	914	50—65
9	New Bedford	C. i., w. i. & cement lined.	4—30	29,139	10,114	72.2	16 55		1.1	43	585	66	808	29—40
10	New London	Cast iron & cement lined.	4—20	10.374	0	40.2	28.11	1.5	2.4	14	176	16	200	45—50
11	Newton	Cast iron.	4—20	24,729	0	109.7	12.60	0.1	2 7	32	736	30	564	84
12	Oberlin	"	4—12	3.412	0	7 1				5	66	7	42	28 - 32
13	Plymouth	Cement lined iron.	2—20	5,735		33.	6.74	1.	9.5	1	102	12	297	
14	Quincy	Wrt. i., kal. and cast iron.	2—20	35,570	490	44.8	5.41	0.7	5.	51	186	64	450	70—80
15	Reading	Cast iron.	4—12	989		18.	2.36	0.01	0.	0	103	4	176	68—78
16	Springfield	W. i., w. i. c. l. & cst. i.		28,544	5,658	103.		0.36		24	691	84	1,208	H. S., 80-115. L. S., 30-35
17	Taunton	Cast iron.	4—20	6,390		69.	20.56			35	658	21	452	45—50
18	Toronto	"	3—36	14,685	8,668	244.96	68.6			69	2,827	76	1,988	20—80
19	Troy	"	4—30	2,059		58.	7 00	0 6	0.6	19	736	28	1,170	11—107
20	Waltham	C. i. & w. i. cement lined.	2—24	7,712		45.9	15.75	0.7		8	250	34	509	55
21	Wellesley	Cast iron.	4—12	2,057		24.2	1.19	0.4	0.5	15	176	5	157	70
22	Woonsocket	"	4—20	4,757		37.8	3.68	0.5	none	8	463	13	406	90—115
23	Yonkers	"	4—30	25,124		47.5	12.71			36	513	36	308	

TABLE V. — DISTRIBUTION,— SERVICE PIPES.

Number.	Name of City or Town.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26a.	26b.	27.	28.
		Service pipe.					Service taps.				Meters.			Motors and Elevators.	
		Kind of pipe used.	Size of pipe in inches.	Length of pipe extended. Feet.	Length of pipe discontinued. Ft.	Length in use. Miles.	Number added.	Total number in use.	Av. length of service.	Av. cost of service.	Number added.	Now in use: Domestic.	Now in use: Manufactg'.	Number added.	Total in use.
1	Bay City	Ld. wrgt.i. & wyckoff pat.	¾ to 8				76	1,793			66	459		7	63
2	Boston, Coch.	Lead and cast iron.	¾ to 6	37,881			1,512	66,586			134	4,046			539
3	" Mystic	Lead and wrought iron.	¾ to 4	23,100			810	22,398			26	461			21
4	Brockton	c. l. i.	1 to 2	4,273		16.7	175	3,650	24	8.37	235	2,258			
5	Burlington	Lead and g. i.	½ to 4	1,546	46	14.4	57	2,664	28	8.00	57	665	46		17
6	Fall River	Lead.	¾ to 2				267	5,793			277	4,529			12
7	Fitchburg	Wt. i. c. l. & cast iron.	¾ to 8	10,005		40.17	202	3,571	56	7.49	149	1,283	113	9	51
8	Lynn	gal. i. c. l. adamanta.	¾ to 10	24,275	2,162	90.3	562	11,103			175	669			
9	New Bedford	Lead and cast iron.	¾ to 8	14,081	88	46.6	400	7,531	35	15.42	28	113	59	0	31
10	New London	c. l., gal., Lead & c. i.	½ to 4	1,788	38	8.9	107	2,464	19.1	10.21	20	149		0	25
11	Newton	Lead, wrgt. & cast iron.	½ to 4	14,479	0	61.4	279	5,281	61.3	$28 62 net 15.33	324	3,865	22	0	16
12	Oberlin	Galvanized iron.	¾				70	328	25	6.52	36	66	5	0	0
13	Plymouth	Lead—c. l. i.	½ to 1	437		5.5	43	1,543	18.5	4.28					1
14	Quincy	Lead and g. i.	¾ to 2				275	1,889	19		24	91			
15	Reading	g. i.—c. l. i.—l. l. i.—c. i.	¾ to 6	6,886	74	7.6	97	600	71	25.01	8	24	1	1	1
16	Springfield		¾ to 6				367	7,000			274	1,590		6	92
17	Taunton	Cement lined wt. iron.	¾ to 3	5,070	4,356	35.2	117	3,635		43.67	99	1,132	98		13
18	Toronto		¾ to 6				526	39,927	33			1,510			90
19	Troy	Lead and cast iron.	¾ to 6				177	6,458			9	248			
20	Waltham	Cast iron, wt. i. c. l.	¾ to 6	7,284		32.5	109	2,920	68.7	24.40	21	80		0	11
21	Wellesley	" "	¾ to 6	3.851		10.	27	610	148	11.85	402	561	5	0	2
22	Woonsocket	Lead and iron.	¾ to 6	2,101			122	1,621	17.6	13 25	105	1,366	40	0	5
23	Yonkers	Lead and cast iron.	¾ to 8	No account kept.			235	3,250			211	3,140	108	1	9

INDEX TO ADVERTISEMENTS.

RUBBER GOODS. PAGE.

Boston Belting Co 24

LEAD AND LEAD PIPE.

Boston Lead Manufacturing Co 11
Chadwick Lead Works 10
Tatham and Brothers 9

CAST-IRON PIPE AND SPECIALS.

McNeal Pipe and Foundry Co. 18
Builders Iron Foundry. 17
Emaus Pipe Foundry. 16
Jackson & Woodin Manufacturing Co 16
R. D. Wood & Co. 15
Warren Foundry and Machine Co 17
The Radford Pipe and Foundry Co 19

GATES, VALVES AND HYDRANTS.

Crosby Steam Gage and Valve Co 12
Chapman Valve Manufacturing Co 13
Peet Valve Co 14
Ludlow Valve Mfg. Co 12
Rensselaer Manufacturing Co 11

PUMPS.

The E. P. Allis Co 21
Deane Steam Pump Co 20
Alexander E. Schnee 22

BRASS GOODS AND TAPPING MACHINES.

Peck Bros. & Co 9
Walworth Manufacturing Co 8

PACKING.

Gould Packing Co 23
Randolph Brandt 22

METERS.

Henry R. Worthington 3
Hersey Manufacturing Co 4
National Meter Co 2
Thomson Meter Co. 5
Union Water Meter Co 6
Fuel and Gas Manufacturing Co 7

CEMENT.

Lawrence Cement Co. 23

TOOLS.

Perrin Seamans & Co 26

BRIDGES AND STAND PIPES.

Berlin Iron Bridge Co. 25

DRAWING TOOLS, ETC.

Frost & Adams 19
Dame, Stoddard & Kendall 27

ADVERTISEMENTS.

Journal of the New England Water Works Association 27

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GEM,
EMPIRE
WATER METERS

NATIONAL METER CO.,

298 Broadway, New York.

John C. Kelley, Pres't. *159 Franklin St., Boston.*

DECEMBER, 1894. s. d.m. j.

THE WORTHINGTON WATER METER.

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"UNEQUALLED FOR ACCURACY AND DURABILITY."

All parts constructed of Iron and Brass.

The Counter movement is not exposed to the action of the Water.

Positive in operation.

Simple in construction.

Accurate in Registration.

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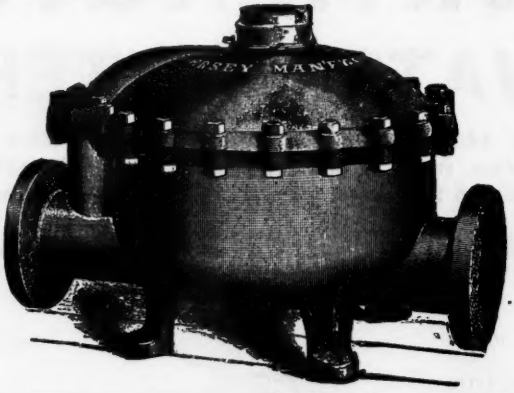

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Water Works Appliances.

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We have established Agencies for the convenience of distant customers as follows:

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THE LARGEST EXCLUSIVE

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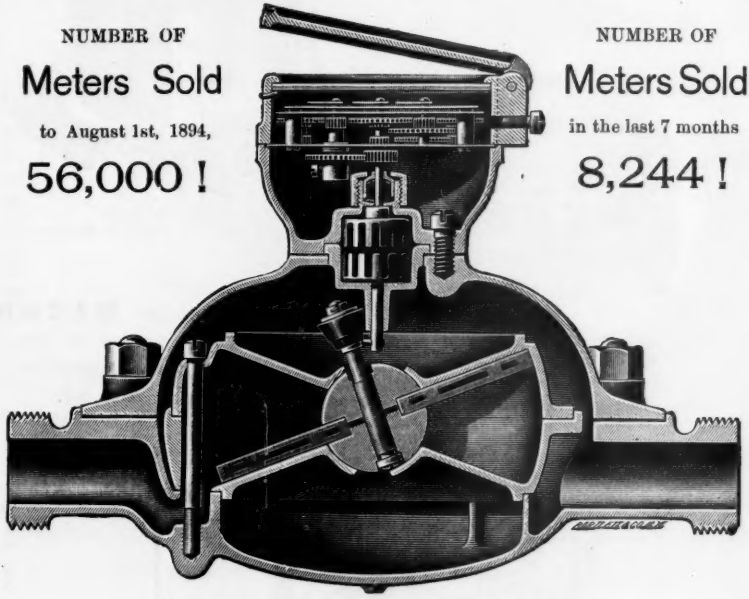

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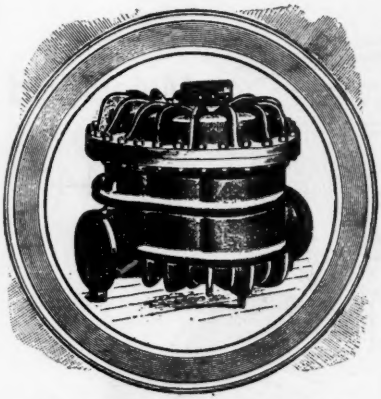

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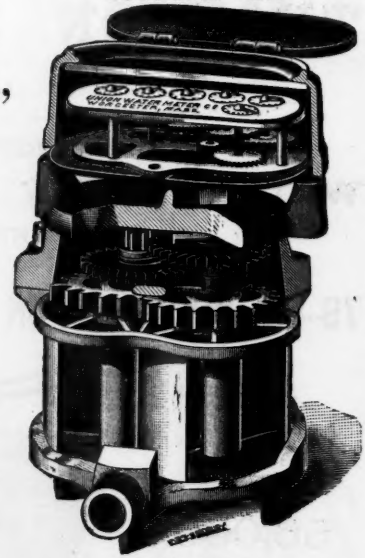

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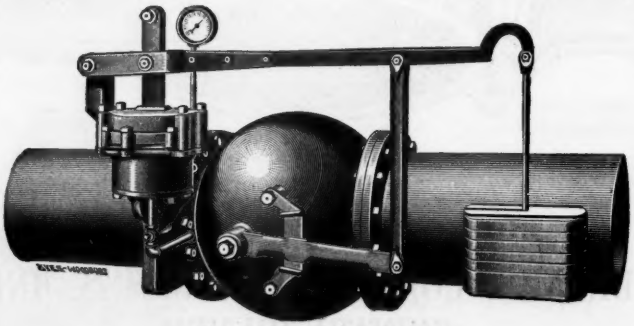

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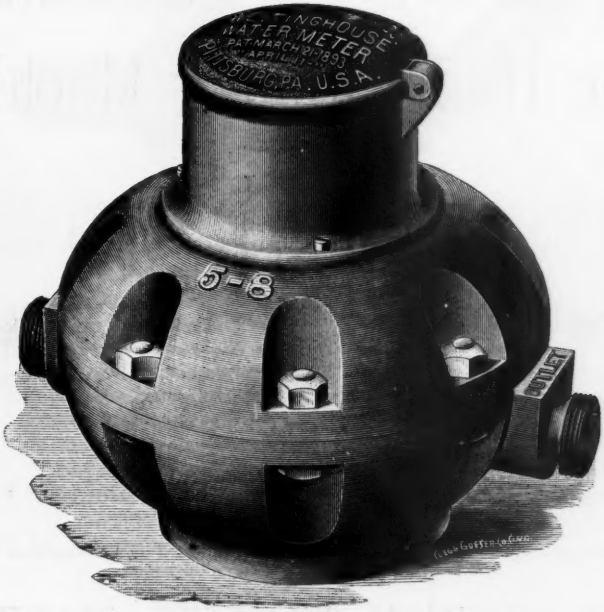

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The dial made to indicate the measurement either in gallons or cubic feet as may be desired. All the claims which we make for this Water Meter will be fully sustained, and we invite Water Companies and Water Departments to make a personal examination and test of it, for which we will be pleased to furnish a reasonable number of meters on sixty days' trial, after which they may be paid for or returned.

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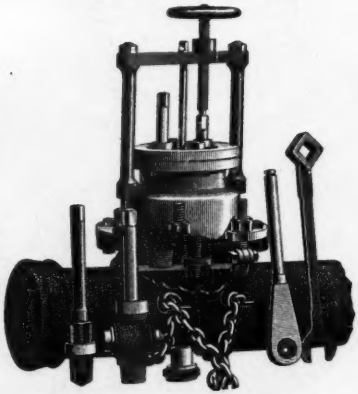

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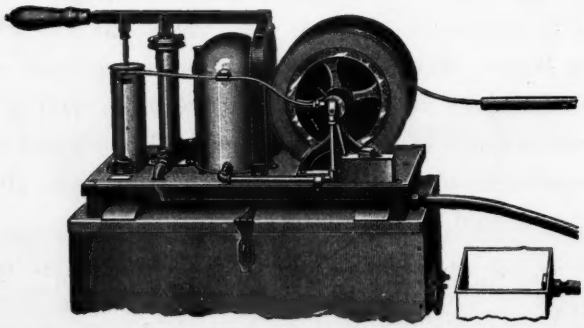

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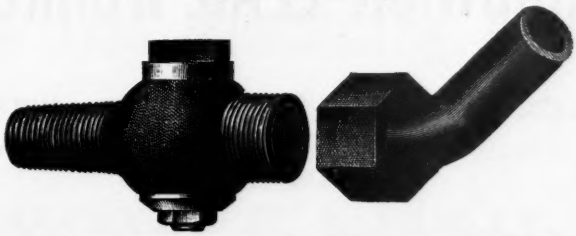

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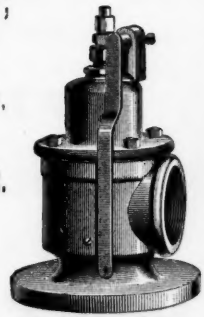

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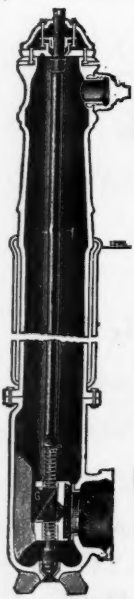

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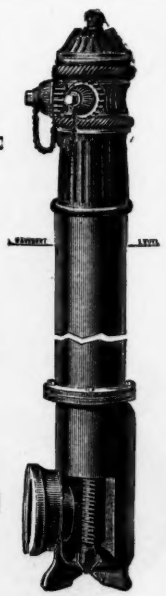

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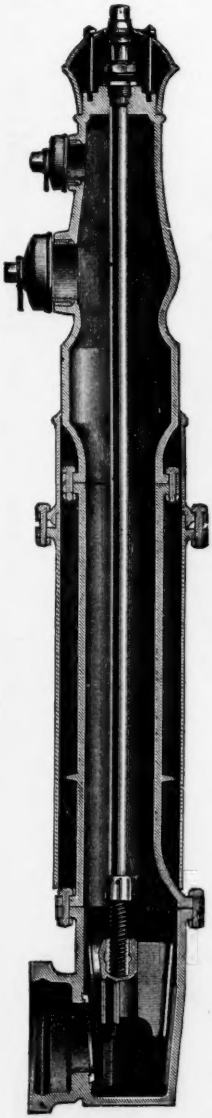

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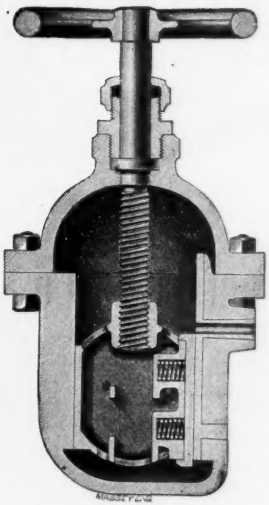

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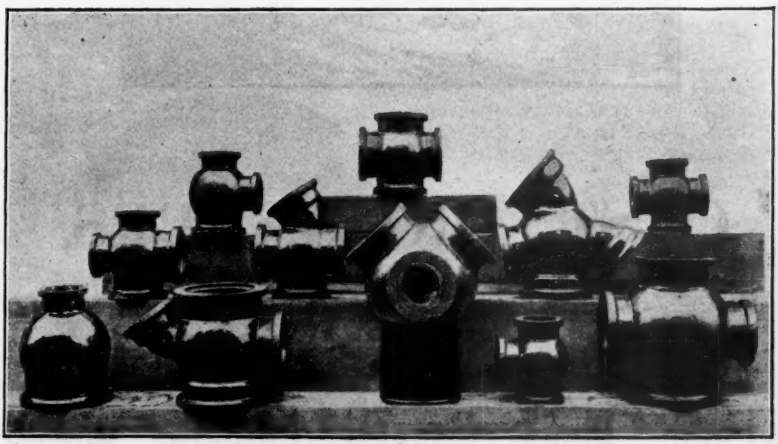

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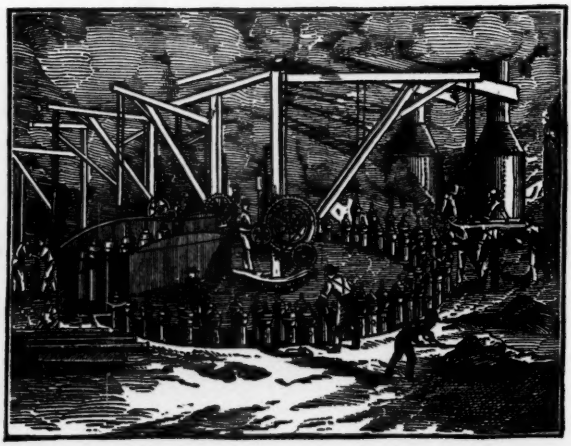

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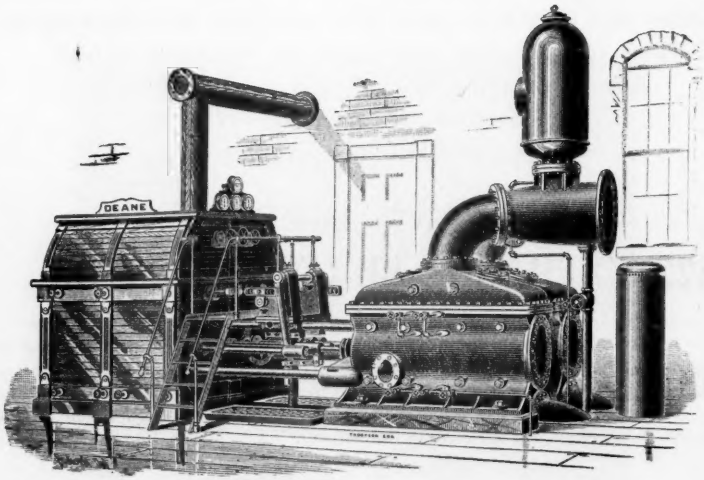

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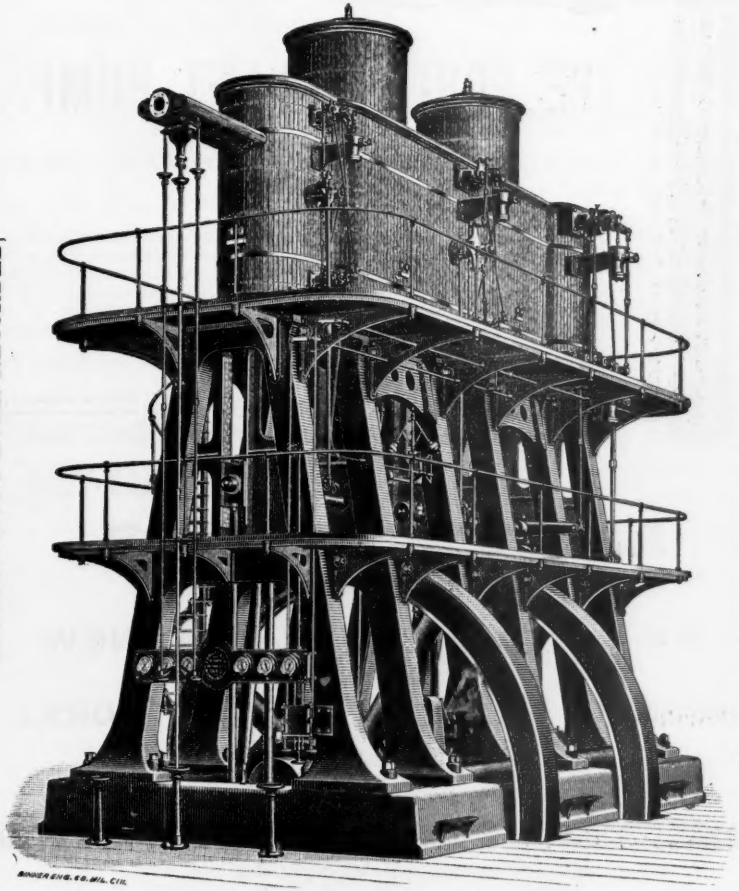

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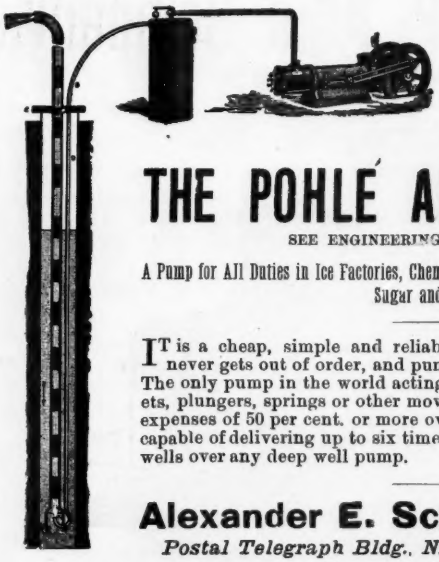

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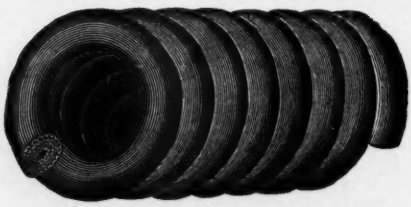

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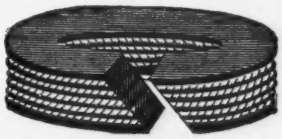

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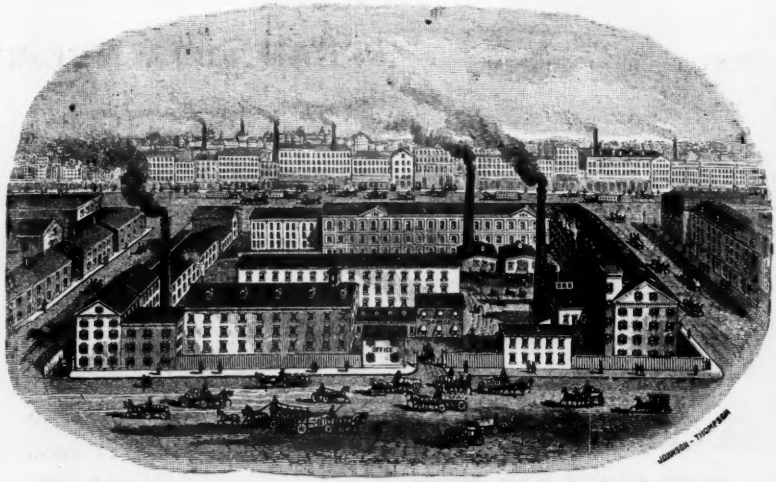

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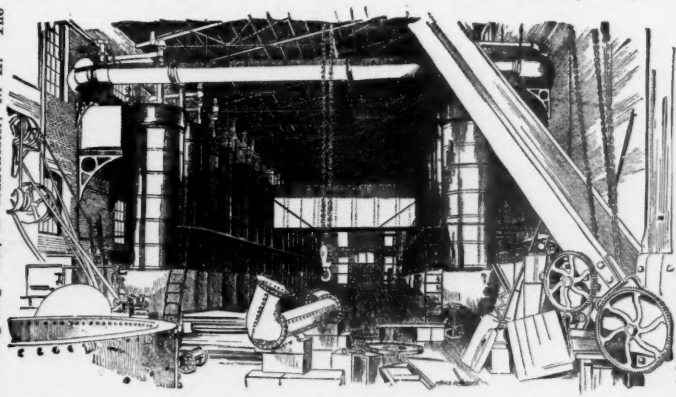

This illustration is taken direct from a photograph, and shows the interior of a boiler house, the roof of which was designed and built by us for The Amoskeag Mfg. Co., at Manchester, N. H. The building is 75 feet in width by 275 feet in length, the walls being made of brick, and the roof being made of iron—iron trusses, iron purlins and covered with corrugated iron, so that there is absolutely no woodwork about the building which can take fire. For boiler rooms this construction particularly commends itself.

This illustration is taken direct from a photograph, and shows an iron and steel water tower designed and built by us for the New London Water Works, at New London, Conn. The tower is 68½ feet in height, and the tank is 25 feet in diameter and 26 feet high. The construction commends itself to engineers as being better and more economical than the ordinary construction of a boiler tube tower the full height.

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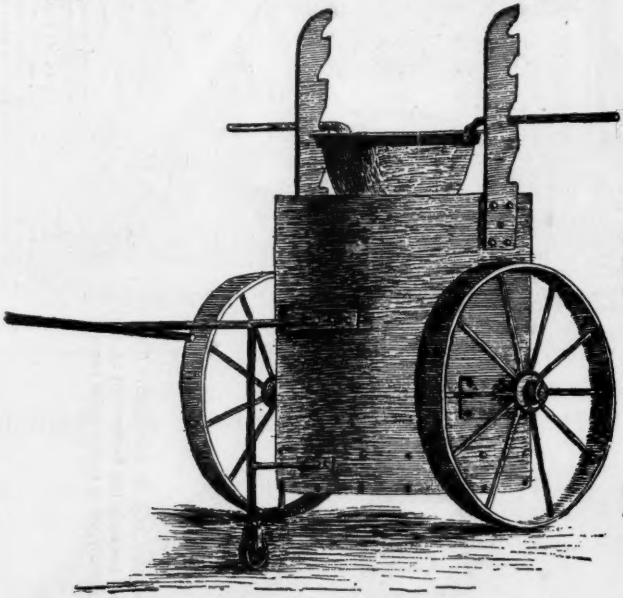

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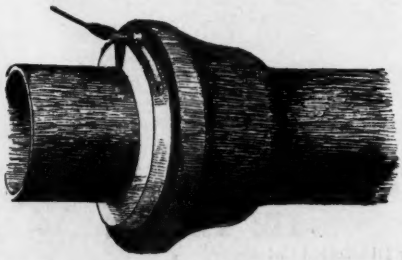

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